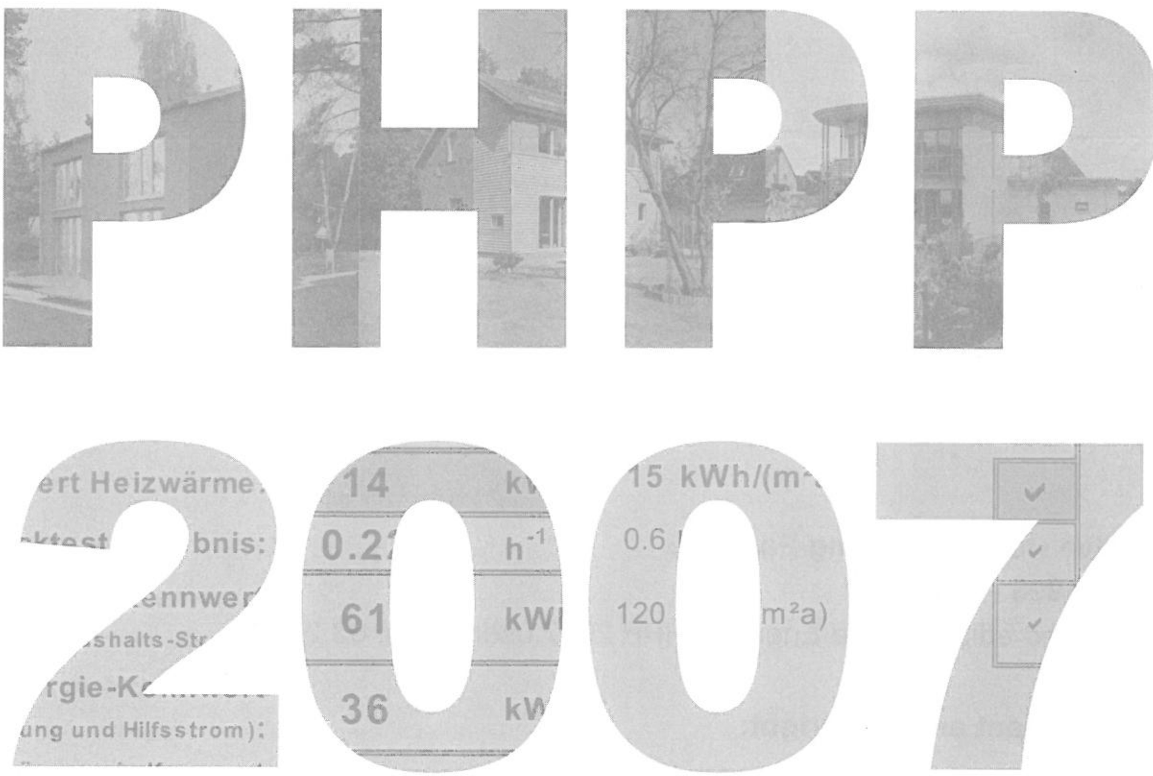
PASSIVE
HOUSE
INSTITUTE
Dr. Wolfgang Feist

Technical Information PHI-2007/1(E)

Passive House Planning Package 2007



Requirements for

Quality-Approved Passive Houses

Passive House Planning Package
PHPP 1998 - 2007
2nd revised edition of the English PHPP 2007 user guide, 03.2010

Development and Copyright:

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Passive House Planning Package 2007

Requirements for Quality-Approved Passive Houses

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Darmstadt, June 2007

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System requirements:

Microsoft® Windows 95 or higher
Microsoft® EXCEL® 2000 or higher

To the authors' knowledge, the PHPP can also be used under OpenOffice (Version 2.2 or higher) and on Macintosh computers. However, no systematic tests on this have been carried out. So there is no warranty given, that this will work under all circumstances.

The authors reserve the right to adapt the content of worksheets to the progress of science and technology.

The Passive House Institute

was founded by Dr. Wolfgang Feist in 1996. The institute specializes in research and development in the field of highly efficient energy use. The Passive House energy standard increases energy efficiency in residential buildings by a factor of 10.

The Passive House Institute offers the following services:

- Accompanying physics research: on site measurements, analysis
- Dynamic building simulations for existing and new buildings
- Computational fluid dynamics (CFD)
- Two- and three-dimensional heat flow calculations, dynamic heat flow simulations
- Ventilation system measurements (air flow rates, temperature, humidity, etc.)
- Quality assurance, Passive House certification
- Field measurements, short and long term
- Indicator gas measurements with non-toxic tracer gas
- Consulting on product development
- Certification of building products for Passive Houses
- Daylighting simulation
- Blower-door tests
- Infrared thermography
- Software development
- Seminars and conferences
- Expert reports

Acknowledgements

The expansion of the PHPP 2007 regarding its application in warm countries, especially the development of the **Cooling, Cooling Units** and **Cooling Load** worksheets and the revision of the **Summer** worksheet were made possible by the fact that the *Passive House Institute* took part as a subcontractor of the Politecnico di Milano in the EIE Save Project Passive-On, Marketable Passive Homes for Winter and Summer Comfort (Project Number EIE/04/091/S07.38644), and by the kind support of BASF AG, Ludwigshafen, Germany.

The project group was made up of:

- Politecnico di Milano, Dipartimento di Energetica, end-use Efficiency Research Group (eERG), Milano, Italy
- Natural Works – Projectos de Engenharia, Lisboa, Portugal
- International Conseil Communication Efficacité Energie (ICE), Ile-Saint-Denis, France
- National Institute of Engineering Technology and Innovation (INETI), Lisboa, Portugal
- University of Nottingham – School of the Built Environment (SBE), Nottingham, UK
- Provincia di Venezia – Assessorato Politiche Ambien, Venezia, Italy
- Rockwool Italia, Iglesias, Italy
- Andalusian Association for Research and Industrial Cooperation (AICIA), Sevilla, Spain

The work on the internationalisation of the PHPP 2007, especially the expansion of the area of application of the routines for orientation and shading on climates outside Central Europe, the integration of additional climate data and the simplification of the translatability, were made possible by the fact that the *Passive House Institute* took part as a subcontractor of proKlima, Hanover, Germany in the EIE Save Project PEP, *Promotion of European Passive Houses* (project number EIE/04/030/S07.39990) and also by the kind support of proKlima, Hanover, Germany.

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- Energieonderzoek Centrum Nederland (ECN), Le Petten, Netherlands
- Arbeitsgemeinschaft Erneuerbare Energie – Institut für Nachhaltige Technologien (AEE INTEC), Gleisdorf, Austria
- SINTEF – Stiftelsen for industriell og teknisk forskning ved Norges Tekniske Høgskole, Trondheim, Norway
- Ellehauge & Kildemoes (E&K), Aarhus, Danmark
- Passiefhuis-Platform vzw (P.H.P), Berchem, Belgium
- proKlima GbR bei der Stadtwerke Hannover AG, Hanover, Germany
- DVH Building and Industry (DHV), Amersfoort, Netherlands
- Building Research Establishment Ltd. (BRE), Watford, UK
- National University of Ireland (NUID), Dublin, Ireland
- Technical Research Centre of Finland (VTT), Espoo, Finland

PHPP 2007 – User Registration

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Passive House Planning Package PHPP 2007 Registration

Please fill in the following questionnaire and send it to the *Passive House Institute* at the above address. You will automatically receive e-mail information about software updates. Moreover this registration is required to get a discount on the purchase of future versions of the PHPP

Last Name, First Name

....

Company / Institution

....

Address

....

Zip Code / Postal Code

....

Telephone

....

Fax

....

E-Mail

....

☐ IG Passivhaus Member

Profession:

☐ Architect

☐ Structural Engineer

☐ Mechanical Engineer

☐ Building Product Manufacturer

☐ University or Research Institution

☐ Consultant

☐ General Contractor

☐ Future Home Owner

☐ ....

☐ Please check this box, if you do not wish to receive information via e-mail.

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Passive House Planning Package 2007

Foreword to the Revised Edition 2007

Since the publication of the last edition of the PHPP in 2004 the Passive House has gained a considerably growing public interest. Against the background of the recent discussion on the acceleration of climate change also the public in general has realized that there is no alternative to a dramatic improvement of energy efficiency.

Passive Houses are no longer futuristic and exotic pies in the sky. They now comprise a considerable proportion of new builds in Germany, Austria and the northern part of Italy. The Passive House idea is gaining ground beyond Central Europe, offering economically viable highly comfortable housing. Pilot projects, including adaptation of building components and strategies, are underway in all European countries. Not only that: also in Minnesota, California, South Korea and China.

This fact made it necessary to carry out considerable further development of the PHPP. The treatment of orientation and shading, as well as of heat losses to the ground, was designed in a way that it can be used independently of climate and location. The most extensive improvement is the calculations for summer conditions. The existing **Summer** worksheet has been revised and algorithms for highly efficient, active cooling have been added.

Increasing numbers of non-residential buildings e.g. schools and office buildings are being developed according to the Passive House standard. As an aid to the development of such projects, worksheets for the calculation of electricity demand and internal heat gains in non-residential buildings have been provided.

The target of the PHPP is and remains that it should be a design tool. It provides the architect and the mechanical engineer with all instruments which are necessary for the design of a well-performing Passive House. The examples that have been realized up to now show how diverse the designer's possibilities are. Sustainable buildings to the Passive House standard can be realized at any location in the world, and since they reduce ongoing energy consumption by at least a factor four in comparison with that of other types of new builds, they can be permanently integrated into a structure of sustainable energy production

First English Edition 2004 Foreword

The successfully engineered Passive House concept has caught the attention of professionals in many countries all over the world who recognise it as an astounding opportunity to live sustainably without compromising modern comfort demands. What is most needed in order to support the implementation in many different countries are design tools and literature on Passive House design principles and technologies. As a first step, the *Passive House Institute* offers its Passive House Planning Package to the international community. The present software and manual are mainly a translation from the original German "Passivhaus Projektierungs Paket". A few items have been added, such as a selection of climate data for Europe and North America. On the other hand, some features suited specifically for German users have been omitted, e.g. most references to German building legislation. [...]

First German Edition 1998 Foreword

Is a detailed dynamic energy simulation program required to plan every Passive House? Even a few years ago, that was the case. From experience we know now that in most cases stationary energy balancing procedures deliver sufficiently accurate results for Passive Houses. They can be validated beforehand by means of dynamic simulations. Therefore it is possible to greatly simplify the Passive House design process for normal buildings using a relatively simple software tool. Certain factors remain difficult to predict, like summer temperatures or the influence of thermal storage capacity. Those can only be estimated with sufficient accuracy by performing a dynamic building simulation.

C. U. Brunner published the first ideas for a seasonal energy balance during the mid-eighties in Switzerland. The method was first introduced in Switzerland by the recommendation SIA 380/1 "Energie im Hochbau" (Energy in Buildings) in 1988. Wolfgang Feist, Witta Ebel and Tobias Loga contributed further significant developments from 1989 to 1995 at the German "Institut Wohnen und Umwelt" (Institute for Housing and Environment). While planning the construction of the first Passive House, the method was adapted to the special boundary conditions of superinsulated buildings which no longer require a conventional heating system.

New Features in the Passive House Planning Package 2007

Many changes have been implemented in the new version of the PHPP, including data input simplification, increased algorithm precision and improvements based on practical experience. In particular, the following worksheets have been considerably changed and expanded:

Summer Case

Summer	The summer season calculation methods, which have already proven to be accurate, were revised and now explicitly consider ground coupling, solar irradiation absorbed by the outer surfaces and various nighttime ventilation strategies.
Ground	For the summer case, an additional series of ground temperatures is now calculated.
Areas	The radiation balance of outer structural building components is now considered.
SummVent	Various window ventilation flows can now be displayed side-by-side.
New: Cooling	The cooling load is calculated for the cases in which active cooling is required
New: Cooling Units	The energy demand for latent loads (i.e. air dehumidification) is estimated.
New: Cooling Load	This worksheet determines the maximum cooling performance demand as a daily average.
PE Value	The cooling demand, if present, is included in the primary energy balance.

Internationalisation

Climate Data The structure and handling of this worksheet was redesigned to increase user-friendliness. Numerous additional climate data, in particular complete climate data sets for Eastern Europe, Austria, Switzerland and important European cities, are included.

Window Shading The algorithms for calculating the solar gains are now valid outside Central Europe.

Ventilation A climate-independent efficiency instead of the heat supply efficiency is given for the subsoil heat exchanger.

Non-residential Buildings

New: Electricity NonDom By means of this new worksheet the electricity demand for lighting, electronic devices and kitchens in non-residential buildings can be calculated.

New: IHG Non-Dom This new calculation worksheet serves to predict and verify the internal heat gains of non-residential buildings.

New: Use Non-Dom Utilization profiles for predicting the electricity demand and the internal heat gains of non-residential buildings are embedded in this new worksheet; several profiles can be defined.

Compact Heat Pump Units

Compact The worksheet has been completely revised to account for the certification of compact heat pump units that began in 2007.

The following changes are noteworthy for experienced users of the PHPP:

- The Temperature Zone "D" for roofs open to the sky was previously needed to represent the solar heat loads through the roof in the summer worksheet correctly. In the PHPP 2007 the solar heat loads through opaque exterior building elements are calculated explicitly. Thus the distinction between exterior walls and roof is not necessary anymore.
- The order of window orientation, solar radiation, etc has been standardized. It is now organised clockwise according to compass directions - north, east, south, west. This must be kept in mind when transferring projects from the PHPP 2004.
- The heating demand balance in the left hand side of the Monthly Method worksheet no longer refers to the whole year but only includes the months in which the building actually needs to be heated.
- The efficiency of heat recovery of subsoil heat exchangers is no longer entered. It has been replaced by a (climate independent) efficiency ranging from 0 to 100 % (refer to the explanations in the **Ventilation** worksheet).

We would like to thank you for the tremendous feedback pertaining to the experience gained from the use of the PHPP in practice. We are happy to continue receiving both positive comments and constructive criticism concerning the new version.

Darmstadt, June 2007

The authors of the PHPP

1 First Steps

When opening the PHPP for the first time, you are faced with a multitude of worksheets. If you are not familiar with the functions and the use of the PHPP, we recommend entering a simple example, following the step-by-step procedure outlined below. If you experience any difficulties you can refer to the sample-PHPP and to the corresponding chapters in the manual.

If possible base your exercise on the building plans of a small residential building.

Open the file *PHPP2007_English.xls* on the CD in MS-Excel.

Limit this exercise to the calculation of the main criterion for Passive Houses, which is the heat demand, calculated in the **Annual Heat Demand** worksheet. Only completion of the worksheets **U-Values**, **Areas**, **Windows** and **Ventilation** is required for this calculation. All other values are set to default values if the corresponding cells are left blank. All input cells have a yellow background.

Enter values for the individual construction elements of all opaque areas of the thermal envelope into the U-Values worksheet, including roof, exterior walls and floor slab (or basement ceiling when the cellar is not heated). The building element sections can be entered in any order. As an interim result you get the corresponding calculated u-values.

Enter the areas of the opaque thermal envelope into the **Areas** worksheet using exterior dimensions. Windows and doors are currently included as part of the walls. Window areas are automatically subtracted when specified in the **Windows** worksheet, whereas exterior door areas must be subtracted manually. In the column "Group Nr." you enter for example 8 for the exterior walls (Exterior Wall – Ambient Air; refer to the list in the upper part of the worksheet). In the column T please chose one of the assemblies which you have entered in the **U-Values** worksheet.

Please enter the treated floor area (heated space area or living area) as well.

Check the summary in the upper part of the worksheet. From now on you can watch the changes to the specific space heat demand, while making new entries.

Insert window data in the **Windows** worksheet. The drop-down menus allow you to specify in which wall a window is installed, as well as the type of glazing and frame (scroll down to display all choices). Under "Installation" enter "0" if the corresponding side of the window adjoins to another window and "1" if the window is installed in a wall at this side. In the right hand part of the worksheet some properties of the window are displayed. You will find further results in the upper part of the worksheet.

In the **Ventilation** worksheet choose a ventilation unit in the drop-down menu in row 58.

The **Annual Heat Demand** worksheet will now display the calculated space heat demand.

This first result represents a rough estimation. It will be refined further into the planning process.

Chapter 4 includes an overview of all PHPP worksheets and their correlations.

2 Introduction

2.1 Designing Passive Houses

Passive Houses are very well insulated and draughtproofed buildings whose annual space heat demand is so low that the conventional heating system can be omitted. The small amount of heat still required can be delivered to the individual rooms by heating the air supplied by the ventilation system. This will work, when the space heating energy demand is up to 15 kWh/(m²a) (kilowatt-hours per square meter of treated floor area per annum).

The construction of a Passive House is very demanding in terms of the performance of the building components used. The following reference values apply to the Central European climate. The principles are valid in other climates as well.

- Exterior building elements must have a U-value below 0.15 W/(m²K)
- The external envelope must be constructed without thermal bridges (see chapter 7.9).
- The airtightness of the building envelope should be verified by means of an air leakage test complying with the DIN EN 13829 standard. The measured air leakage must not exceed 0.6 h^{-1} at a pressure differential of 50 Pa (for both over and under-pressurisation).
- All glazing must have U-values below 0.8 W/(m²K) according to the European standard EN 673 and a high total solar energy transmittance (g) of at least 50 % according to EN 410 to achieve net heat gains in winter.
- Windows must have total U-values under 0.8 W/(m²K) according to DIN EN 10077.
- The ventilation system must be designed with the highest energy recovery efficiency ($\eta_{HR} \geq 75$ % complying with PHI certification; for results from standard testing procedures 12 percentage points have to be subtracted). It must also have minimal electricity consumption ($\leq$ 0.45 Wh/m³ supply air volume).
- Domestic hot water generation and distribution systems with minimal heat losses must be used.
- Highly efficient use of household electricity is essential.

Simply combining appropriate components is not sufficient to construct a building as a Passive House – the integration as a whole is greater than the sum of the individual parts. The component interaction necessitates an integral plan in order to achieve the Passive House standard. This is the purpose of this Passive House Planning Package.

2.2 Residential Use

All calculations are based on a constant room temperature of 20 °C and do not consider nighttime temperature lowering. In buildings with very good thermal insulation, the effect of lowering the temperature at night is negligible. A temperature of 20 °C is normally ensured by means of suitable heating systems controls.

For reasons of energy efficiency and hygiene a Passive House requires a ventilation systems with high-efficiency heat recovery. Since this guarantees a good indoor air quality in this type of building throughout the heating period ventilation through open windows is unnecessary. This does not mean that it is 'forbidden' to open the windows, only that it is not required. However, opening the windows in the heating period costs money because of the extra loss of heat - just like in any other type of building. It is important to consider that only the heat actually stored in the air extracted by the ventilation system can be reused. No calculation procedure or system is able to account for uncontrolled ventilation through open windows because the behaviour of individual inhabitants is unknowable. Statistical information from Passive House developments show that only a few individuals tend to use additional window ventilation, and even in these cases the Passive House principles were shown to work – of course at a correspondingly higher energy consumption [Ebel 2003], [Reiß/Erhorn 2003].

The *Passive House Institute* offers a standard Passive House user manual which is easily customized by adding project-specific information. This manual should be made available to house owners, home buyers and tenants. It is a available as a free download from www.passiv.de (German-language only).

2.3 Use in Modelling Non-residential Buildings

Besides residential buildings, other building types can, in principle, be designed as Passive Houses with the PHPP 2007. However, the use-specific boundary conditions must be appropriately adapted. For example, the internal heat gains deviate noticeably from the standard residential values. For nursing homes, office and government buildings, and schools, predefined standard values are included. When the intended use of the building does not correspond to one of these types, then the internal heat gains must be calculated via the **IHG** (see Chapter 34) or **IHG Non-Dom** worksheet and in many cases the **Use Non-Dom** (see Chapter 36).

Non-residential buildings are often only temporarily occupied (e.g. offices on workdays during office hours). Therefore, it is logical to operate the ventilation and heating systems intermittently, which is not the case for residential buildings. This can lead to a significant decrease in total energy demand, even in Passive Houses, which, in turn, effects the heating load and ventilation design.

When determining the maximum heating load, the additional load for reheating the building after periods of inactivity must also be considered. If radiators are used, a longer preheating period can be chosen to decrease the maximum load. If, however, heating is provided via the supply air, then the preheating period should not exceed the period required for pre-ventilation of the building (approx. 1 to 2 hours before start of utilization period, see [AkkP 33], [prEN 15251]). Otherwise, the ventilation system would solely be used to heat the building during preheating. This can significantly increase the electricity demand of the ventilation system, due to the generally high air exchange rate in non-residential buildings (see [AkkP 33] in German). For the intermittent operation of a heating system, an extra preheating load must be considered for the dimensioning. In this case, the necessary extra load must be specially calculated; the calculation in the **Heating Load** worksheet is not suitable.

The intermittent operation leads to lower average temperatures compared to the building's target temperature, which leads to lower heat losses. The average room temperature can also be used for predicting the heat demand in the PHPP 2007.

shows the temperature correction factors for two different workday utilization patterns. The temperature correction values were calculated via dynamic simulation during the core winter heating period[1] .

[1] At the start of the intermittent operation, the room temperature decreases exponentially at a rate that depends on the building constant and the outside temperature. Therefore, the average room temperature cannot be modeled as the time-average of a step function (in use 20 °C / out of use 17 °C). For light and heavy construction types, the same use yields the same temperature correction terms $\Delta\theta$ (see in German [AkkP 33]).

Table 1: Determination of the average room temperature for static energy balance calculations. $T_{target} + \Delta\Theta = T_{average}$.

Operation on workdays from		Solid Construction	Light Construction
7:00 to 14:00	$\Delta\Theta$	-1.0 K	-1.0 K
7:00 to 18:00	$\Delta\Theta$	-0.6 K	-0.6 K

2.4 Installation Recommendations

The enclosed CD ROM contains the PHPP calculation files in Excel® 2000 format as well as an already filled in file with the exemplary project "Darmstadt Kranichstein".

The worksheets have been created using MS-Excel® (for Windows from version 95 and MS Office from version 2000). They can be used with newer versions of the software as well. To the authors' knowledge the PHPP can be used with only minor restrictions with OpenOffice from Version 2.2 as well as on Apple Macintosh computers. However, this has not been systematically tested.

The data files can be installed on the hard drive by simply copying them into a folder. In order to work with the worksheets, select the empty calculation file, copy it to a working folder and rename it using the project name.

2.5 Excel and the PHPP

Microsoft® Excel® is a flexible worksheet software. The main advantage is that dependent calculation results are updated even when parts of the previous calculations are altered. All calculation algorithms of the PHPP are based on linked data.

Please create back-up copies of your work frequently. If embedded links or formulae are erased, they can easily be recreated from the back-up copy. Moreover you should create a back-up copy of the original data files before starting to work with the worksheets.

2.5.1 Assistance with Entering Data in the Passive House Planning Package

The PHPP has instructive notes built into the worksheets that can be selected at will. A red indicator in the upper-right corner of a cell shows that instructive notes are available. The notes are exposed by moving the mouse over the cells. The comments are designed to assist with entries, indicating what information should be entered and offering useful advice on how to use the calculation sheets.

2.5.2 The Cell

The cell is the calculation unit in Excel. Formulae, alphabetic or numeric values can be input in a cell. There is always an active cell in a worksheet which is shown by highlighting. Enter data in this cell.

A formula can refer to the data contained in other cells. A formula always begins with a "=" and is followed by a mathematical equation. On the screen, every cell displays the result of its formula. The formula bar at the top of the screen displays the equation for the highlighted cell and allows the user to manipulate the formula.

2.5.3 Cell Links

When values are to be shared between two different worksheets, a link between cells can be created. Consider the example of sharing a U-value between the **U-Value** and **U-List** worksheets:

Type "=" in the cell where the information is to be displayed in the U-List sheet. Go to the **U-Value** worksheet, and click on the cell with the desired U-value and press "Enter". The data is then linked between worksheets and is updated automatically when the content of the original cell in the U-values worksheet is modified.

Links can also be created for other data files using the same process. Information is readily available using links and can easily be applied to create synopses for larger projects or apply source data sets to the calculations. We recommend saving and leaving all linked data in a separate file folder to ensure that work can continue on the project easily.

2.5.4 Copying Cells

Cells can be copied either individually, in columns or in rows. To copy cells, do the following:

- Highlight the cell(s) containing the data to be copied.
- Go to "Edit" in the menu bar and click "Copy". You may also press Ctrl+C.
- Highlight the cell(s) where the information is to be inserted.
- Go to the "Edit" menu and click "Paste". You may also press Ctrl+V. The information is copied to the designated area.

2.5.5 Adding Rows and Columns

If a third row is to be inserted between two existing rows, do the following:

- Highlight the row above which the new row will be inserted.
- Go to “Insert” in the menu bar. Click “Rows”. The row is automatically inserted.

Columns or individual cells can be inserted similarly.

> Please be very careful when inserting cells as hidden formulae can be lost, damaged or contain faulty references. For adding extra rows at the end of a list, please follow exactly the below instructions.

2.5.6 Adding and Copying Extra Rows in a Table with Lists

If more building elements must be added to the lists in the **Areas**, **Windows** and **Shading** worksheets, keep the following considerations in mind:

- Rows should never be added in the very last row, but in the second to last row. This ensures that all sums are correctly updated.
- Enter the new row.
- Completely highlight the previous row, copy, and insert into the new row (the reference row can contain hidden formulae).
- The **Windows**, **Shading** and **Shading-S** worksheets are always edited simultaneously. In these worksheets rows can be inserted directly below the last yellow cell.
- The links of the drop-down menus in the new row must be edited manually to maintain correct links. Copied drop-down menus always retain links to the original cells.

2.5.7 Drop-down Menus in the PHPP

Every drop-down menu is linked to a certain cell, which in the PHPP is frequently located right beside the drop-down menu and is formatted as an entry cell. Instead of using the drop-down menu it is also possible to chose an option by entering the corresponding index from the drop-down menu in this cell or even by entering a formula. This is especially helpful if you want to change a large number of drop-down menus at the same time (e.g. changing the type of the window frame for all windows) or if you don’t want to adjust all drop-down menus after inserting cells. Caution: If you use the drop-down menu for choosing an option after having entered a formula, this formula will be overwritten.

Selection of the Corresponding Building Element Assembly	Nr.	U-Value [W/(m²K)]
Exterior wall	1	0.138

In order to delete the content of the drop-down menu, please enter "0" in the yellow cell.

2.5.8 Instantaneous Display of Results

When optimising building elements entry and result cells are frequently not located on the same worksheet. In order to be able to view the results of your entries immediately, without switching the worksheets, you can open a second display of the same file:

- Menu command Window / New Window

You can now arrange the views in such a way that you can see the entry and the result at the same time.

2.5.9 Hiding Worksheets

You will not need all the PHPP worksheets in every project. To improve clarity, you can hide worksheets which are not needed:

- Highlight worksheets which should be hidden
- Menu command Format / Sheet / Hide

2.5.10 Cancelling Worksheet Protection

The worksheets are guarded against unintentional alterations by worksheet protection. Normally, only the yellow cells can be modified. If other parts of the worksheet must be altered, the following steps are taken to unlock the worksheet:

- In the "Tools" Menu, Select "Protection". A pop-up menu appears. Click on "Unprotect Sheet". The entire sheet is available for editing.

It is not recommended to change the sheets in the PHPP unless absolutely necessary. If PHPP certification as a "Quality-Approved Passive House" is sought after, the algorithms in the worksheets must only be altered after prior consultation with the certifying body.

2.5.11 Print Layout

The print areas are predefined in every worksheet. Cells outside the predefined areas are not printed. If desired, the print areas can be changed:

- In the “View” menu, highlight “Page Break Preview”.
- In the worksheet, select the new range of cells that are to be printed.
- In the “File” menu, click on “Print Area”, and select “Set Print Area”. Saving the document saves the new print area settings.

3 Certification of Passive Houses

The certification of a Passive House by the *Passive House Institute* (PHI), the *Passivhaus Dienstleistung GmbH* or another certifying body which is approved by the *Passive House Institute*, offers additional security. The designer can benefit from the long term experience of the certifying body. The certificate itself proves the particular quality of the building.

Information about the certification is offered by:

Passivhaus Dienstleistung GmbH
Rheinstr. 44/46
64283 Darmstadt
Tel.: 0 6151 / 399 499-0
Fax: 0 6151 / 399 499-11
post@passivhaus-info.de
www.passivhaus-info.de

or by other certifying bodies which are approved by the PHI.

The criteria for certification which apply to residential buildings at the time of printing are described below (criteria for non-residential buildings, please refer to www.passiv.de).

3.1 Evaluation Criteria for the Certification

Specific Space Heat Demand	**max. 15 kWh/(m²a)**
or Heating Load (alternatively)	**max. 10 W/m²**
Pressurization Test Result n_{50}	**max. 0.6 h^{-1}**
Entire Specific Primary Energy Demand	**max. 120 kWh/(m²a) incl. domestic electr.**

If active cooling is necessary, the useful cooling demand must not exceed 15 kWh/(m²a). The primary energy criterion stays unaltered in this case as well. The energy demand for cooling has to be compensated elsewhere.

The reference value (Treated Floor Area) is the net floor area inside the thermal envelope (For further information on how to determine the treated floor area, please refer to chapter 7.8).

The criteria have to be verified with the Passive House Planning Package 2007 (PHPP2007). For the specific space heat demand, the monthly as well as the annual method can be applied. If the space heat demand is below 8 kWh/(m²a) or the relation of free heat to heat losses is above 0.70 in the annual method, the monthly method must be applied.

The most recent certification criteria have to be applied (refer to: www.passiv.de). The calculation method described in the PHPP handbook and the PHPP software is subordinate to this.

3.2 Documentation Required for the Passive House Quality Approval Certificate

PHPP (signed) containing at least the following calculations (please enclose the calculations as MS-Excel file or send them via e-mail)

	Name of Worksheet
Property details and Passive House verification	**Verification**
Organisation of areas with allocation of U-values, radiation balance data and thermal bridges	**Areas**
Calculations of U-values of regular building elements	**U-Values**
List of the building elements used	**U-List**
Calculation of window U-values	**Windows**
List of employed windows and glazing	**Win-Type**
Reduction factors for building elements against the ground, applicable cases	**Ground**
Shading factor calculations	**Shading**
Calculations of air flow rate and efficiency of heat recovery; analysis of pressurization test results	**Ventilation**
Verification of space heat demand using the PHPP annual method	**Annual Heat Demand**
Verification of space heat demand using the PHPP monthly method (if selected in the **verification** worksheet)	**Monthly Method**
Heating load verification using the PHPP	**Heating Load**
Calculation of the frequency of overheating in summer	**Summer**
Summer shading factor determination	**Shading-S**
Determination of summer ventilation (if applicable)	**SummVent**
Heat loss of space heating and DHW distribution systems	**DHW + Distribution System**
If a solar collector is used, calculation of the solar fraction for DHW	**SolarDHW**
Seasonal efficiency of the heat generator	**Compact, Boiler or District Heat**
Calculation of the electricity demand	**Electricity**
Calculation of the auxiliary electricity demand	**Aux Electricity**
Calculation of the primary energy demand	**PE Value**
Selection of climate data, if "standard" is not used	**Climate Data**
Verification of the useful cooling energy demand, if active cooling is used	**Cooling**
Verification of the cooling load, if active cooling is used	**Cooling Load**
Calculation of the cooling units, if active cooling is used	**Cooling Units**

3.2.1 Planning documents for design, construction and building services:

- Site plan including the building orientation, neighbouring constructions (position and height), prominent trees or similar vegetation, possible horizontal shading from ground level elevations; photographs of the plot and surroundings. The shading situation must be comprehensible.
- Design plans (floor plans, sections, elevations) as pre-construction plans 1:100, or implementation plans 1:50 with comprehensible dimensioning for all area calculations (room dimensions, envelope areas, rough window opening sizes).
- Location plan of envelope areas and windows, also thermal bridges if present, for allocation of the areas or thermal bridges calculated in the PHPP.
- Detail drawings of all building envelope connections, e.g. the external and internal walls at the basement ceiling or floor slab, external wall at the roof and ceiling, roof ridge, verge, installation situations of windows at sides, above and below, anchorage of balconies etc.. The details should be given with dimensions and information about materials and thermal conductivities. The airtight level should be indicated and its connection points for the implementation should be described.
- Building services plans – ventilation: representation and designing of ventilation units, volumetric flows (Final Protocol Worksheets Ventilation, see PHPP CD), sound protection, filters, supply and extract air valves, openings for transferred air, external air suction and exhaust air outlet, dimensioning and insulation of ducts, sub-soil heat exchanger (if present), regulation, etc..
- Building services plans – heating/plumbing: representation of heat generators, heat storage, heat distribution (pipes, heat coils, heating surfaces, pumps, regulation), hot water distribution (circulation, single pipes, pumps, regulation), domestic hot water distribution (circulation, single pipes, pumps, regulation), cold water pipes, drainage with aeration including their dimensioning and insulating standards.
- Building services plans – electrical (if used): illustration and designing of lighting and elevator.

3.2.2 Proofs, technical information, with product information sheets if applicable:

- Manufacturer, type and technical information sheets, especially of insulation materials with very low conductivity (λ < 0.035 W/(mK)).
- Itemisation of a comprehensible calculation of the treated floor area
- Information about the window and door frames to be installed: manufacturer, type, U_w value, $\Psi_{Install}$, $\Psi_{Glazing\ Edge}$, graphical representation of all planned

installation situations in the external wall. The calculation values should be mathematically computed according to DIN EN 10077-2. For products which have been certified[2] by the Passive House Institute, these verifications are available.

- Information about the glazing to be fitted: manufacturer, type, build-up, U_g-value according to DIN EN 673 (to two decimal places) g-value according to DIN EN 410, type of edge spacer.
- Evidence of the thermal bridge heat loss coefficients used in the PHPP according to DIN EN ISO 10211. Alternatively, comparable documented thermal bridges can be referred to (e.g. from certified Passive House construction systems, PHI publications, Passive House thermal bridge catalogues).
- Short description of the planned building-technical supply systems, with schematic drawings if applicable.
- Manufacturer, type, technical data sheets of all building-technical components: ventilation system, heat generator for heating and hot water, heat storage, insulation of ductwork and pipes, heater coils, frost protection, pumps, elevator, lighting etc..
- Information about the sub-soil heat exchanger (if present): length, depth and type of installation, soil quality, size and material of tubing, verification of the heat recovery efficiency (e.g. with PH-Luft[3]). For sub-soil brine heat exchangers: regulation, temperature limits for winter/summer, verification of the heat recovery efficiency.
- Information about the length, dimensioning and insulation level of the supply pipelines (hot water and heating) as well as the ventilation ducts between the heat exchanger and thermal building envelope.
- Concept for efficient electricity utilisation (e.g. specified devices, explanation and incentives for the house or apartment owner). If efficient electricity utilisation is not verified, average values of devices available on the market will be set (standard values of PHPP).
- Proof of summertime comfort must be provided for the buildings which are to be certified. The PHPP procedure for determination of summertime overheating only shows the average value for the whole building – however, individual parts can overheat. If this is suspected, a detailed analysis should be carried out.

[2] Data sheets for certified components can be found on the internet at www.passiv.de

[3] PH-Luft: A programme which assists planners of Passive House Ventilation systems. Free download from www.passiv.de.

3.2.3 Verification of the airtight building envelope according to DIN EN 13829

In variation from DIN EN 13829, a series of measurements each for overpressure and underpressure is necessary. The pressure test is to be carried out only for the heated building envelope (basement, porches, conservatories etc., which are not integrated into the thermal building envelope, should not be included in the test). It is recommended that the test be carried out when the airtight level is still accessible and eventual improvements can be carried out. The calculation of the indoor air volume should also be documented in the pressure test report.

Basically, an institution or person independent of the contractor or building owner should carry out the pressure test. A pressure test which is carried out by the contractor will only be accepted if a person signs the test report for the accuracy of the information on his own responsibility.

3.2.4 Adjustment protocol of the ventilation unit

The protocol must at least include the folllowing: description of the property, location address, name and address of the tester, time of adjustment, manufacturer and model of ventilation unit, adjusted volumetric flows per valve for normal operation, mass flow/volumetric flow comparison for outdoor air and exhaust air (maximum disbalance of 10 %). Recommendation: Use “Final Protocol Worksheets Ventilation”, source PHPP CD or www.passiv.de.

3.2.5 Declaration of the construction supervisor

Implementation according to the certified Passive House project planning must be documented and confirmed with the construction site supervisors's declaration. Any variation in implementation should be mentioned, for deviant products corresponding evidence must be provided.

3.2.6 Photographs

Photographs which document the construction of the Passive House should be provided; digital images are preferable.

3.2.7 Other Evidence

It may be possible that additional test reports or data sheets for the components used in the building are required. If values which are more favourable than those in the standard PHPP procedure are to be set, these should be supported by detailed evidence.

3.3 Procedure of the Quality Approval

An informal application for the certificate can be made to the selected certifier. The required documents must be filled in completely and submitted to the tester. The documents must be checked at least once. Depending on the procedure, further testing may also be arranged.

Note: If possible, checking of the documents relevant for the Passive House standard should be carried out during the planning stage so that potential corrections or suggestions for improvement can be considered at an early stage. If there is no experience with Passive House construction, a preliminary consultation, and if applicable, project-accompanying advice is recommended.

After the assessment the contractor will receive the results, with corrected calculation and suggestions for improvement, if applicable. It is not the object of the certification to review the construction work, but evidence of the building's airtightness, the adjustment protocol of the ventilation unit and the construction site supervisor's declaration and at least one photograph must be provided. If the technical accuracy of the necessary evidence for the building is confirmed and the criteria given above are adhered to, the following certificate will be issued:

Quality-Approved
Passive House
Dr. Wolfgang Feist

Issuing only certifies the accuracy of the documents submitted, in accordance with the level of technological development of the Passive House standard. The assessment relates neither to the monitoring of the work, nor to the supervision of the user behaviour. The liability for the planning remains with the responsible technical planners, and the liability for the implementation lies with the appropriate construction management. The Passive House Insitute logo may only be used in connection with certificates.

Additional quality assurance of the construction work by the certifying body is particularly expedient when the construction management has no experience in Passive House construction.

We reserve the right to adapt criteria and calculation procedures to advancing technical development.

3.4 Calculation Methods, Basic Conditions, Reference to Standards

The following conditions or calculation rules should be used in the PHPP:

- Climate data for Germany: either standard Germany or regional data set (suitable for location, for deviating altitudes with temperature correction of -0,6 °C per 100 m difference in altitude).
- Climate data for other countries: regional data set (suitable for location, for deviating altitudes with temperature correction of -0,6 °C per 100 m difference in altitude).
- Individual climate data: applicability is to be agreed previously with the relevant certifier.
- Designed indoor temperature: 20 °C without night-time set-back.
- Internal heat sources: 2.1 W/m², in case no other national values have been set by the PHI.
- Occupancy rates: 35 m²/person, deviating values of 20 - 50 m²/person are permissible if justified (actual occupancy or designed input)
- Domestic hot water demand: 25 litres per person per day, 60 °C, cold water temperature 10 °C, provided that no other values have been set by the PHI.
- Average ventilation volumetric flow: 20-30 m³/h per person, but at least a 0.30-fold air change with reference to the treated floor area multiplied by 2.5 m room height. The applied air mass flows must correspond to the actual adjustment values.
- Household electricity demand: standard values according to the PHPP, deviating values only if individually verified by the building constructor or by electricity planning.
- Thermal envelope area: Exterior dimension reference without exception.
- U-value of opaque building components: PHPP procedure according to EN 6946 with rated values of the conductivity according to national standards or building authority regulations.
- U-values of windows and doors: PHPP procedure according to EN 10077 with mathematically computed rated values for the frame U-value U_f, glass edge thermal bridge Ψ_g, installation thermal bridge $\Psi_{Install}$.
- Glazing: mathematically computed U-value U_g according to EN 673 (to two decimal places) and g-value according to EN 410.

- Heat recovery efficiency: Testing method according to the PHI (see www.passiv.de), alternatively, testing according to the DIBt method (German Institute for Building Technology) or equal with a deduction of 12 %.
- Efficiency of the heat generator: PHPP procedure or separate verification.
- Primary energy factors: PHPP dataset.

Detached house in Geretsried, Germany
Photo: Hawran

4 Sequence of Entries

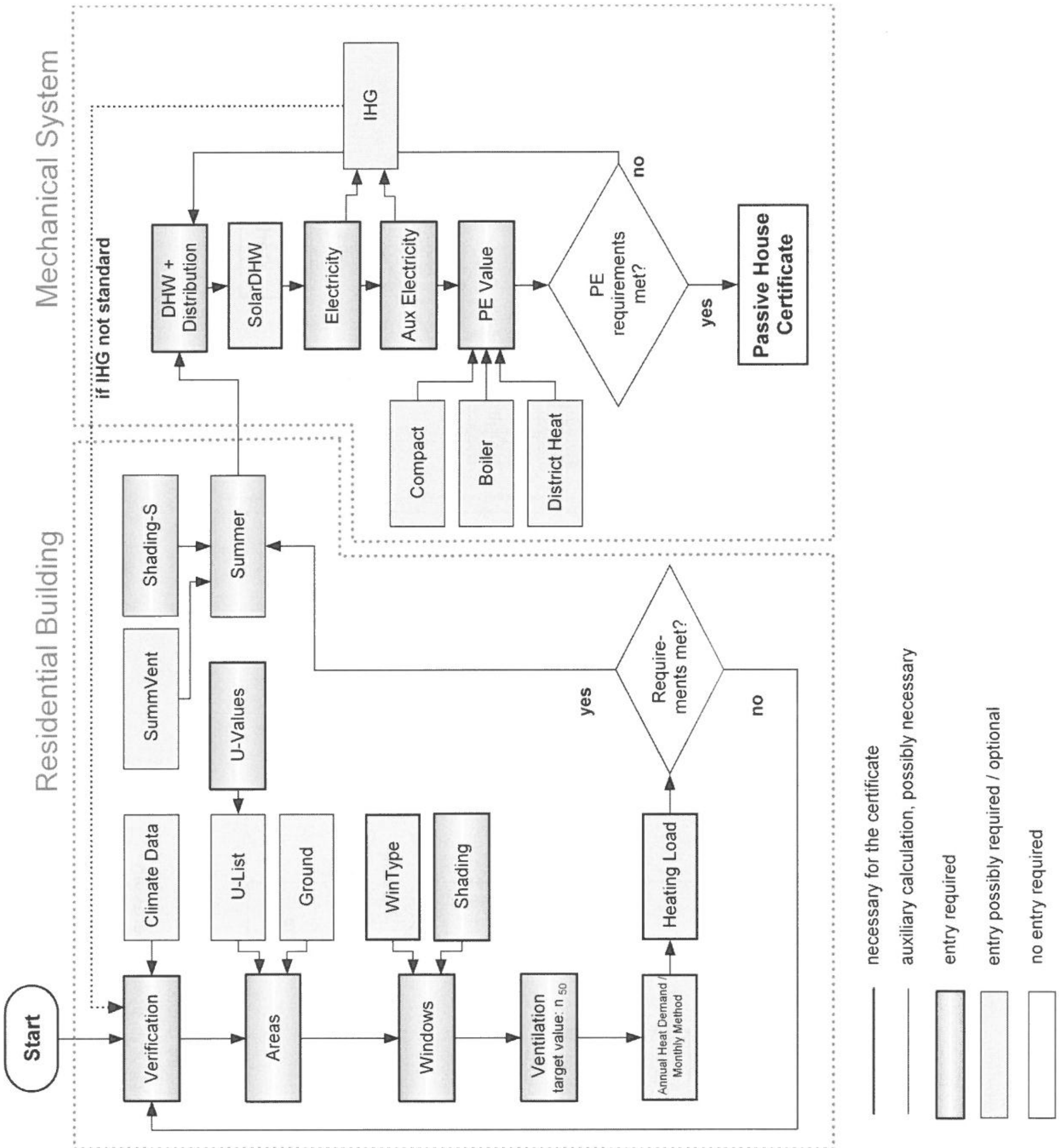


Figure 1: Input sequence (residential building)

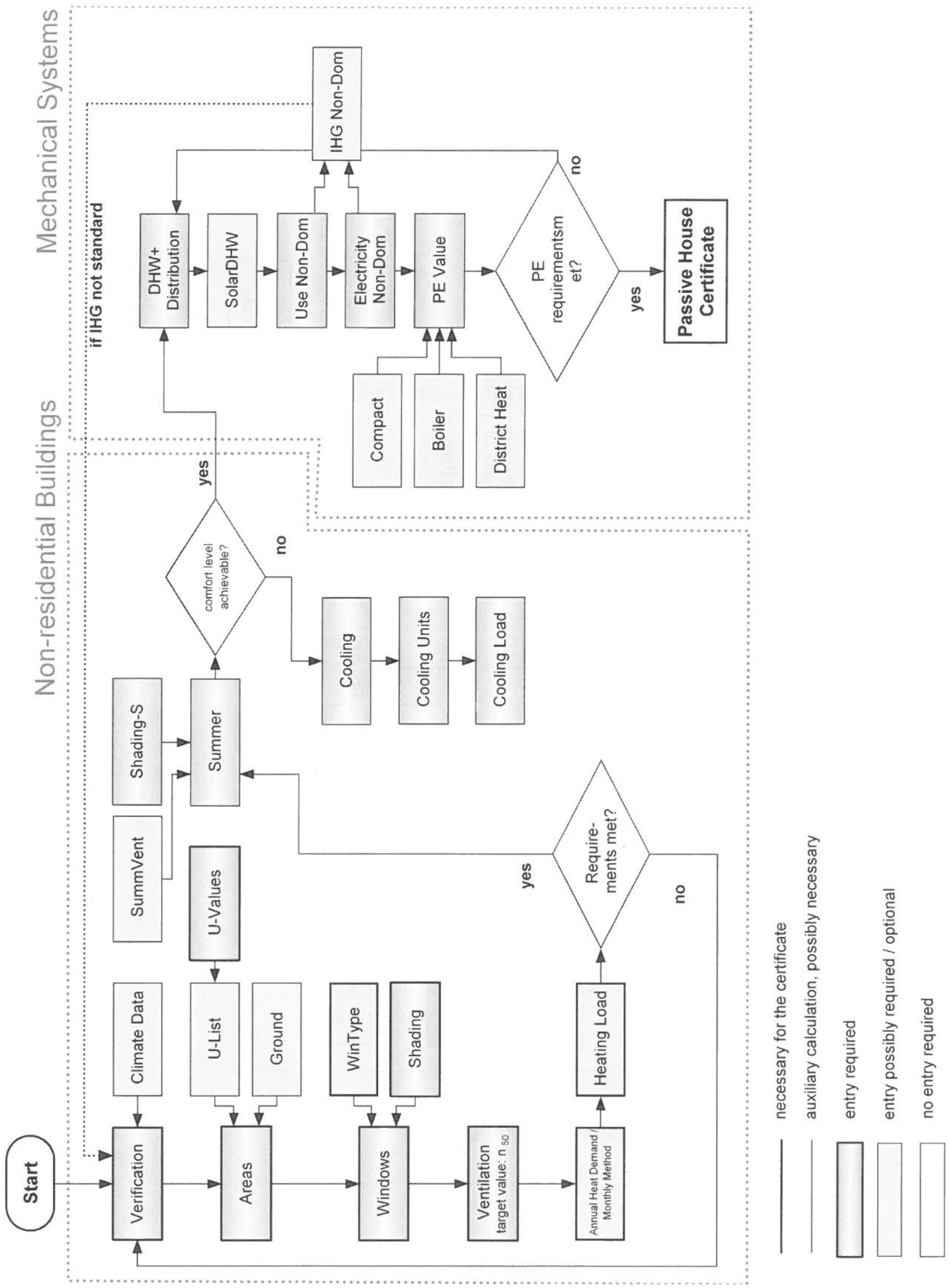


Figure 2: Input sequence (non-residential buildings)

5 "Brief Instructions" Worksheet

An overview of the worksheets and the meaning of the cell formats is found in this table.

Yellow Cells with blue text require user inputs to be applied in additional calculations.

The sheets in the PHPP are write-protected to prevent formulae from being inadvertently erased or modified. Only yellow data entry cells with blue text can be edited. The user can cancel worksheet protection if the program must be modified to suit a specific project. To prevent the loss of information and hidden formulae, worksheet protection should only be suspended if absolutely necessary. The chapter entitled "Excel and the PHPP" contains instructions on worksheet protection.

Changes to **White and Green Cells** should be avoided if possible. The cells contain references to other worksheets (purple text), fixed values, or formulae (black text).

Green cells signify important calculation results.

Recommendation: Before beginning to work with the worksheets, prepare a back-up copy of the original data. The information can easily be re-entered if hidden links or formulae are erased unintentionally.

Riedberg-school in Frankfurt
Photo: Passive House Institute

6 "Verification" Worksheet: Building Data Documentation and Passive House Standard Verification

The most important project data, like building designation, address, homeowner, designer, enclosed volume, and the expected number of occupants, are entered in this worksheet.

At the top of the worksheet room is left blank for a photograph of the project. For inserting the picture the worksheet protection has to be cancelled.

All values for the verification process are based on the treated floor area (TFA) for the dwelling, which is basically the net usable floor area. It can be entered in the **Areas** worksheet. Take great care in the determination of this value. A detailed explanation on how to calculate the TFA is given in chapter 7.8.

The **Verification** sheet is used for Passive House certification. The certification criteria are detailed in chapter 3.

6.1 User Dependent Data and Standard Use

6.1.1 Interior Temperatures

The interior design temperature used for planning and verification is 20 °C. It should only be changed in justified cases.

6.1.2 Internal Heat Sources

The selection of the internal heat sources in the **Verification** worksheet can be made at the right edge of the sheet.

- First the type of building (residential / non-residential) as well as the type of building use (Residence, Assisted Living, Office, School, other) has to be chosen. The value for the internal heat sources for the verification is then entered automatically.
- For the Passive House verification select "Standard" for the type of values used.
- When designing for cases with different heat gains, (select “PHPP-Calculation”) or for buildings in the “Other” building categories, the total sum of the internal heat sources is then entered directly into the **IHG** or **IHG Non-Dom** worksheet. See the corresponding chapters for necessary entries.

Frequent Mistake

> When designing non-residential buildings in many cases an individual determination of the internal heat sources is necessary. The internal heat sources have a great impact on the space heat demand. Standard values can only be used with specific types of building use.

6.1.3 Number of Occupants

The selection of the number of occupants is entered at the right hand side of the page. When "Verification" is selected, 35 m²/Person is automatically chosen as the standard occupancy rate. This selection is required for the Passive House certification.

For manual input of the number of occupants select "Planning". Then you can enter the number of occupants. The occupancy rate is limited between a minimum of 20 m²/Person to a maximum of 50 m²/Person. This range takes into consideration that the occupancy rate may vary over the lifetime of the building.

For non-residential buildings the number of occupants has to be entered manually.

6.2 Selection of the Calculation Method

In the non-printable area one of the following calculation methods can be selected:

- The annual method in accordance with EN 13790, using the annual climate data balance over the heating period.
- The monthly method in accordance with EN 13790, using monthly climate data to determine the sum of the monthly balances during the heating period.

The user selects the corresponding field from the drop-down menu.

Verification: Monthly Method

Specific Space Heat Demand, Annual Method	13.8
Specific Space Heat Demand, Monthly Method	13.5

In most cases, both calculation methods deliver results with negligible differences. Previous experience has shown that the annual method can produce results that are too low if the project has an annual heating demand lower than 8 kWh/(m²a). This is why the annual method is only valid for projects with annual heating demands over 8 kWh/(m²a) and a ratio of free heat to heat losses above 0.7.

6.3 Climate Region

By default, standard climate data for Germany is used. However, it is also possible to use climate data for other regions.

A different climate region can be selected in the **Climate Data** worksheet. The applicable climate region is shown in the "Location and Climate" portion of the **Verification** worksheet.

6.4 Calculation Results

The **Verification** worksheet is also the cover sheet for the Passive House quality approval certificate. Here the most important results and the respective requirements are summarized:

- Specific annual space heat demand
- Air leakage test results
- Specific Primary Energy demand
- Space heating load
- Frequency of summer overheating
- Useful cooling demand
- Cooling load

The specific primary energy demand is given both as the total primary energy demand for all purposes, including household electricity, and as the portion of heating, DHW, and auxiliary electricity including ventilation. The maximum value for Passive Houses is 120 kWh/(m²a) relative to the treated floor area of the PHPP including household electricity. If electricity is produced from photovoltaic cells, this is displayed as primary energy saving.

Passive House Verification

Building:	End-of-Terrace Passive House Kranichstein	
Location and Climate:	Darmstadt Kranichstein	Standard Germany
Street:		
Postcode/City:	D-64289 Darmstadt	
Country:	Germany/Hesse	
Building Type:	Terraced House/Dwellings	
Home Owner(s) / Client(s):	Bauherrengemeinschaft Passivhaus	
Street:		
Postcode/City:	D-64289 Darmstadt	
Architect:	Prof. Bott/Ridder/Westermeyer	
Street:	Jahnstr. 8	
Postcode/City:	D-64285 Darmstadt	
Mechanical System:	öeb Dipl.-Ing. Norbert Stärz	
Street:	Bahnhofstr. 49	
Postcode/City:	D-64319 Pfungstadt	

Year of Construction:	1991				
Number of Dwelling Units:	1		Interior Temperature:	20.0	°C
Enclosed Volume V_e:	665.0	m^3	Internal Heat Gains:	2.1	W/m^2
Number of Occupants:	4.5				

Specific Demands with Reference to the Treated Floor Area

	Applied:	Monthly Method	PH Certificate:	Requirement fulfilled?
Treated Floor Area:	156.0	m^2		
Specific Space Heat Demand:	**14**	**$kWh/(m^2a)$**	15 $kWh/(m^2a)$	**Yes**
Pressurization Test Result:	**0.2**	**h^{-1}**	0.6 h^{-1}	**Yes**
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	**65**	$kWh/(m^2a)$	120 $kWh/(m^2a)$	**Yes**
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	37	$kWh/(m^2a)$		
Specific Primary Energy Demand Energy conservation by solar-generated electricity:	33	$kWh/(m^2a)$		
Heating Load:	10	W/m^2		
Frequency of Overheating:	1	%	over 25 °C	
Specific Useful Cooling Energy Demand:		$kWh/(m^2a)$	15 $kWh/(m^2a)$	
Cooling Load:	7	W/m^2		

determined following the PHPP methodology and based on the characteristic values of the building. The calculations with PHPP are attached to this application.

Issued on:

signed:

7 "Areas" Worksheet

The main data entries for the building envelope take place in this worksheet. The project work should begin here and in the **U-values** worksheet. In the PHPP, only the areas of the thermal envelope are considered. Walls, ceilings, etc. in the interior of the building do not have to be treated in detail. According to experienced PHPP users, a majority of the PHPP work has been completed after having listed thermal envelope areas and shading details (see **Shading and Shading-S** worksheets).

The **Summary** section near the top of the **Areas** worksheet contains the summary of all areas relevant for your project. This summary is continuously updated so that an overview of all recorded areas is maintained. This is especially crucial for larger projects. In the **Area Input** section below, the individual sub areas of the thermal envelope are entered. In addition, at the very bottom of the worksheet, thermal bridges can be entered in the **Thermal Bridge Inputs** section.

7.1 Reference to Exterior Dimensions

When planning a Passive House, the first step is to clearly determine the thermal envelope. The thermal envelope influences all other steps in the design process and all calculation results. The envelope has to both enclose the building without interruption, and also comprise the airtight layer. It divides the warm interior area from the exterior cold area and prevents cold air from infiltrating the house.

The dimensions used in the PHPP are always exterior dimensions. Therefore, the dimensions of the most exterior layer of the thermal envelope are to be entered. Cladding elements that are on the exterior side of a ventilated building cavity do not count as part of the thermal envelope. The definition of the exterior dimensions is illustrated in Figure 3.

The closing boundary is located beneath the floor slab, so for the foundation area the reference to exterior dimensions is used as well. Building elements with ground contact get an appropriate reduction factor.

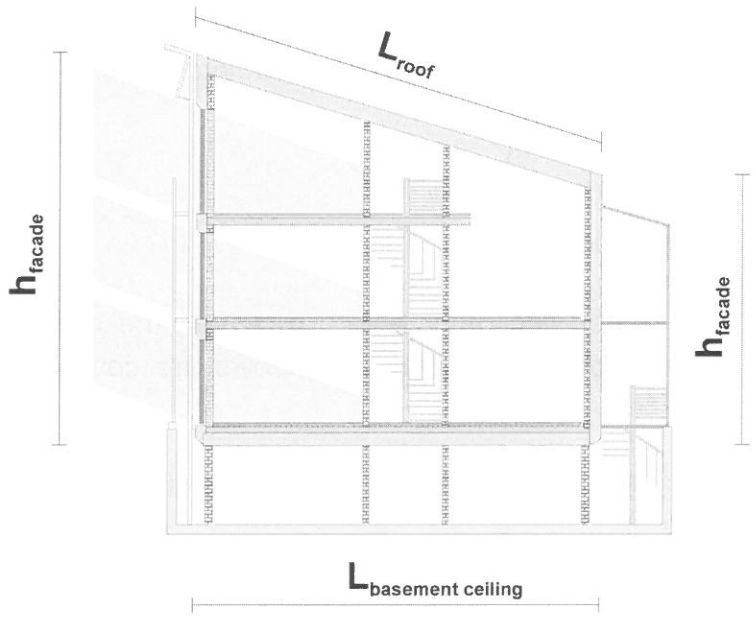


Figure 3: Calculation of building element areas using exterior dimensions

7.2 Summary List of Areas

This section of the worksheet lists the various building element types. In **column D**, "Temp Zone", the reduction factor appropriate for the building element, f_T, is given and is used in the annual heat demand calculation (see Chapter 15.2.1.4). **Column V** contains the average U-value of the building element group. By recording data in the **Area Input** section of the worksheet (starting from row 32) and entering the corresponding group number in **column D** for each area, the areas will then be totalled in the Areas summary within the specific building element group.

Area Group Designations (Group Numbers):

1 Treated Floor Area
2 North Windows
3 East Windows
4 South Windows
5 West Windows
6 Horizontal Windows
7 Exterior Door
8 Exterior Wall - Ambient
9 Exterior Wall - Ground
10 Roof/Ceiling - Ambient
11 Floor Slab

Group Numbers 12-14 are reserved for other group types that can be defined by the user.

Thermal Bridges: Group Numbers 15-17 are reserved for thermal bridge entries (see chapter 7.9). Thermal bridges are broken down into three categories:

15 Thermal Bridges Ambient
16 Perimeter Thermal Bridges
17 Thermal Bridges Floor Slab

Thermal bridges are treated like other areas; however, the unit of measure is "m" instead of "m^2". Thermal bridges related to windows are covered in the **Windows** worksheet.

The last line, Group 18, is for entering values for walls that divide neighbouring buildings (areas in m^2).

7.2.1 Temperature Zones

For each Area Group, one of the following temperature zones must be selected; the selected zone is shown in **Column D**:

A: Interior air against ambient air

B: Interior air against the ground or basement

P: Thermal bridge at the perimeter against the ground

X: Other areas with separately calculated reduction factors (e.g. unheated stairwell). In this case, the value must be entered in the "Reduction Factor" column; the calculated value will overwrite the formula that was originally in the cell.

7.2.2 Temperature Weighting Factors

For the calculation of heat flows through building elements with various temperature differences, appropriate reduction factors are used. The factors are found in **column AG** and correspond to the respective building element groups.

- **Building Elements Exposed to Ambient Air (A)**

Building elements with ventilated constructions are treated the same as building elements exposed to ambient air (e.g. the ceiling under a ventilated roof). Generally, because of the excellent insulation of exterior building elements in a Passive House, determination of reduction factors is not meaningful in these cases. Therefore, for such building elements, the reduction factor is $f_T = 1$.

- **Below Ground Building Elements and Unheated Basements (B)**

The reduction factor to be used depends on the climate and the construction of the building's elements that are in contact with the ground. If the **Ground** worksheet is filled in, the reduction factor will be calculated there. In all other cases, the reduction factor will be approximated, independently of the building, in the **Climate Data** worksheet. In both cases, f_T will be automatically transferred to the **Areas** worksheet. Typical values for Central Europe range around 0.5.

- **Building Elements Adjoining to other Zones (X)**

In the Figure 4, several stairwell plans are shown as an example, with layouts that are both recommended and not recommended. Fundamentally, the airtight thermal envelope must be precisely defined, designed and constructed.

Advice

> If the stairwell is inside the thermal envelope, the airtight enclosure to the exterior and to the basement is of special importance (due to chimney effect). Pay special attention to the airtight exit and basement doors.

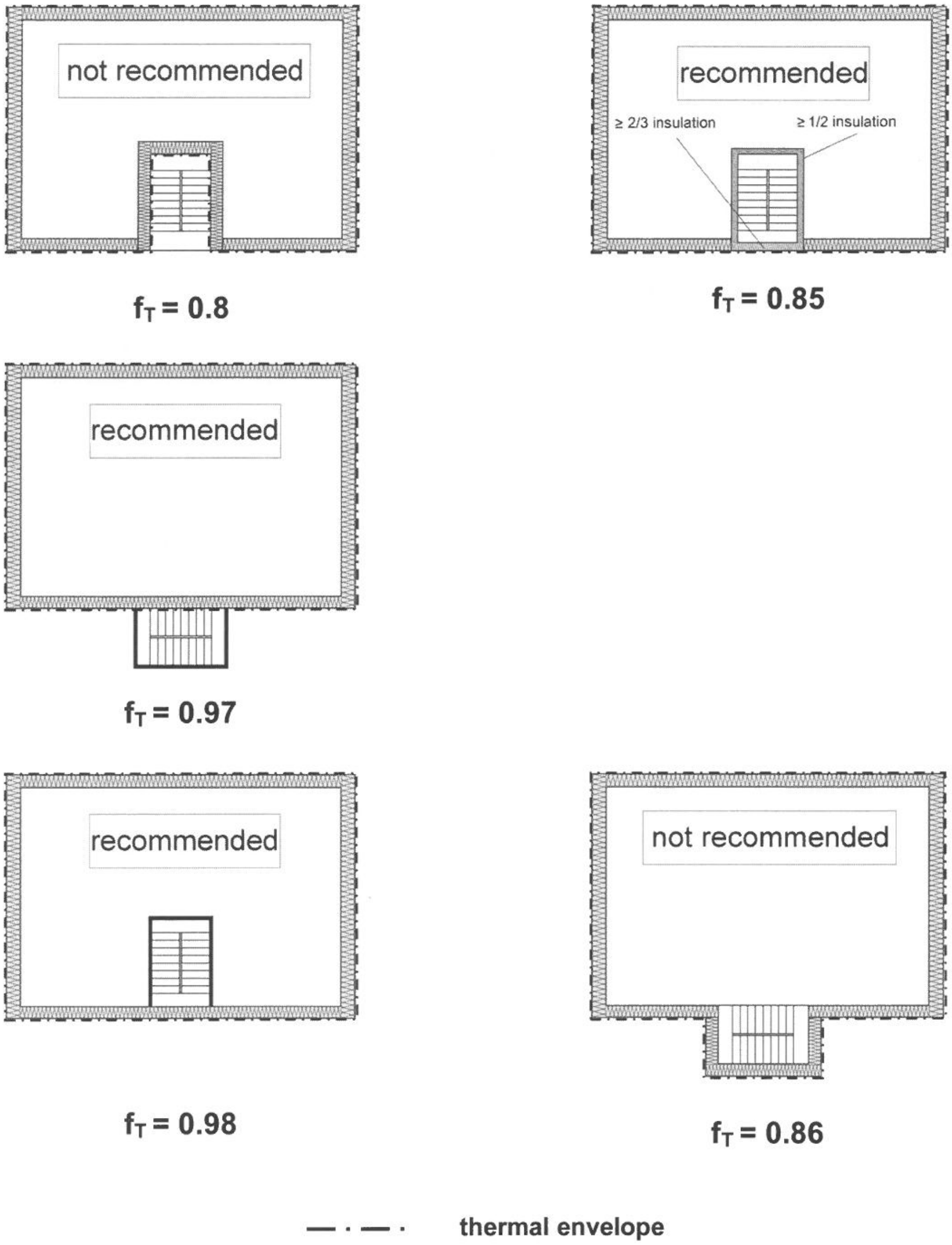


Figure 4 **Various stairwell designs in multifamily residences with corresponding reduction factors, which refer to the thermal envelope areas adjacent to the stairwells.**

In apartment buildings, the staircase to the basement is frequently a critical spot. It is virtually impossible to close the thermal envelope at this area in a correct and thermal-bridge-free manner. Independent of heat losses caused by the enclosing walls of the staircase (the stairwell often acts as a buttress to the building), heat losses result from conduction, radiation and convection. If design and use of the building allows for access to the basement from outside with an unheated stairwell, this is generally the better solution. With this approach, problems with radon infiltration are also reduced. Alternatively, the basement can be integrated into the thermal envelope.

If a stairwell does connect the warm zone with the cold basement, a simplified approach to calculating the heat losses can be taken. First, the exact location of the thermal envelope at this area has to be identified. For the width of the opening that makes up part of this thermal envelope, a U-value of 12 $W/(m^2K)$ can be estimated. With this value, the calculations are on the conservative side. Additionally, conduction heat losses through the opaque boundaries of the thermal envelope in the stairwell have to be taken into account.

Using a more exact but also more time-consuming approach, the percentage of conduction and radiation of the heat loss can in principle easily be calculated. The radiative heat conduction amounts to about 5.5 $W/(m^2K)$. For the convective fraction, an upper limit of 20 m^3/h air change per m^2 open width area has been determined through measurements. For elevators the additional air change, which is generated by the movement of the lift cage, has to be taken into account. From investigations in an eight-storey apartment building, the assumption of a complete air change every ten minutes has proven to be sufficiently accurate [Peper 2006]. For more information (in German) regarding the treatment of stairwells to the cold basement, refer to [AkkP 35].

Passive House Planning

AREAS DETERMINATION

Building: Passive House Kranichstein   Annual Heat Demand: 14 kWh/(m²a)

Summary

Group Nr.	Area Group	Temperature Zone	Area	Unit	Comments
1	Treated Floor Area		156.00	m²	*Living area or useful area within the thermal envelope*
2	North Windows	A	11.04	m²	Results are from the Windows worksheet.
3	East Windows	A	0.00	m²	
4	South Windows	A	30.42	m²	
5	West Windows	A	2.00	m²	
6	Horizontal Windows	A	0.00	m²	
7	Exterior Door	A	0.00	m²	*Please subtract area of door from respective building element*
8	Exterior Wall - Ambient Air	A	184.28	m²	*Window areas are subtracted from the individual areas specified in the "Windows" worksheet.*
9	Exterior Wall - Ground	B	0.00	m²	*Temperature Zone "A" is ambient air.*
10	Roof/Ceiling - Exterior Air	A	83.41	m²	*Temperature zone "B" is the ground.*
11	Floor Slab	B	80.93	m²	
12			0.00	m²	*Temperature zones "A", "B","P" and "X" may be used. NOT "I"*
13			0.00	m²	*Temperature zones "A", "B","P" and "X" may be used. NOT "I"* Factor for X
14		X	0.00	m²	*Temperature zone "X": Please provide user-defined reduction factor (0 < f < 1):* 75%
15	Thermal Bridges to Ambient Air	A	116.85	m	*Units in m*
16	Perimeter Thermal Bridges	P	0.00	m	*Units in m; temperature zone "P" is perimeter (see Ground worksheet).*
17	Thermal Bridges at the Floor Slab.	B	11.35	m	*Units in m*
18	Party Wall to Neighbouring Unit	I	84.84	m²	*No heat losses, only considered for the heat load calculation.*
Total Thermal Envelope			392.07	m²	

Area Input

Area Nr.	Building Element Description	Group Nr.	Assigned to Group	Quantity	x (	a [m]	x	b [m]	+	User-Determined [m²]	-	User Subtraction [m²]	-	Subtraction Window Areas [m²]	) =	Area [m²]
	Treated Floor Area	1	Treated Floor Area	1	x (		x		+	156.00	-				) =	156.0
	North Windows	2	North Windows	Please complete in Windows worksheet only!												11.0
	East Windows	3	East Windows													0.0
	South Windows	4	South Windows													30.4
	West Windows	5	West Windows													2.0
	Horizontal Windows	6	Horizontal Windows													0.0
	Exterior Door	7	Exterior Door		x (		x		+		-		) -		=	
1	Exterior wall south	8	Exterior Wall - Ambient Air	1	x (	7.13	x	10.31	+		-		) -	30.4	=	43.1
2	Exterior wall north	8	Exterior Wall - Ambient Air	1	x (	7.13	x	7.48	+		-		) -	11.0	=	42.3
3	Exterior wall west	8	Exterior Wall - Ambient Air	1	x (	11.35	x	8.89	+		-		) -	2.0	=	98.9
4	Roof	10	Roof/Ceiling - Exterior Air	1	x (	7.13	x	11.70	+		-		) -	0.0	=	83.4
5	Basement floor	11	Floor Slab	1	x (	7.13	x	11.35	+		-		) -	0.0	=	80.9
6					x (		x		+		-		) -	0.0	=	
7	Party wall	18	Party Wall to Neighbouring Unit	1	x (	11.35	x	7.48	+		-		) -	0.0	=	84.8
8					x (		x		+		-		) -	0.0	=	

7.3 Entering Areas for External Walls, Roofs, Ground Floor

The areas can be entered in any order beginning from row 32. The areas are numbered consecutively in **column A, "Area Number"** . The user defines an arbitrary building element description in **column B**. The selection of an appropriate name makes it easier to remember the areas later. By following these steps, the calculations are easier to understand.

A group is to be selected from the above-defined list of building element groups in **column D, "Group Number"**. Through this selection, the user-defined areas are assigned to the selected group, e.g. Exterior Wall group. An input must always be given; otherwise, the particular area will not be considered in the calculation.

The dimensions of the area are to be recorded in **columns G** to **O**. The **columns labelled "a"** and **"b"** are dedicated to the description of the edges of a rectangle. If an area has an unusual geometry, the area can be calculated elsewhere and entered in the **"User-Determined" column**.

It may be necessary to subtract certain areas from the sums calculated up to this point. The PHPP automatically subtracts components entered into the **Windows** worksheet from their respective installation components (walls, roofs/ceilings). All other areas to be subtracted, including entries in the "Exterior Doors" row on this worksheet, must be specified by the user in **column O, "User Subtraction"**.

The resulting calculated area, **"Area"**, appears in **column S**.

7.4 U-Values

U-values are assigned by selecting the appropriate building assemblies from the drop-down menu in **column T** on the right side of the worksheet. U-values for each building assembly must first be entered in the **U-Values** worksheet, and the U-values will then automatically be summarized in the **U-List** worksheet.

The selected U-value automatically appears in **column V**. The calculated temperature specific heat loss of the area, **(H = U • A)**, is the H-value. The calculated H-value appears in **column AF**.

For thermal bridges, the linear thermal transmittance coefficients Ψ are determined instead of U-values. All dimensions primarily refer to exterior dimensions of the insulating envelope (see chapter 7.9).

7.5 Radiation Balance of Roofs and Exterior Walls

The outside surfaces of exterior walls and roofs are heated by solar radiation. However, exterior surfaces of the building also radiate their heat to the night sky. Under clear conditions the sky appears much colder than the ambient air. This lowers the temperature of the outside surfaces to well below the temperature of the ambient air on clear nights.

The opposing influences of solar absorption and radiation to the cold sky roughly compensate for one another in Central Europe during the heating period, as a result they don't have to be taken into account for the total space heat demand. In summer, however, radiant heat loads through solar radiation can become important. Inhabitants of poorly insulated attic apartments can attest to this. The radiation balance of opaque exterior surfaces can therefore be directly considered in the PHPP 2007.

To the right of the areas entry (beginning in **column X**), relevant entries can be made. The following values are required:

- **Exterior Absorptivity:** The absorption coefficient of the building element's surface. This value ranges from 0 (surface with reflective coating/mirror) to 1 (absolutely black surface). Typical values are 0.8 for roof tiles and 0.4 for walls plastered in white. Special paint mixtures can selectively reduce the absorption coefficient of surfaces in the invisible fraction of the solar frequency spectrum without altering the appearance of the surface. With white paint, absorption rates down to 0.1 can be achieved this way.
- **Exterior Emissivity:** The emission coefficient influences heat radiation of the surface to the environment and to the cold sky. In the frequency range of thermal infrared radiation materials can be of differing "brightness" as well. For materials most commonly used in building construction, the emission coefficient is 0.9. Uncoated metals can have values as low as 0.15 even in weathered condition.
- **Deviation from North, Angle of Inclination from the Horizontal:** Please use the same values as in the **Windows** worksheet.
- **Reduction Factor Shading:** Similar to windows, opaque surfaces can be shaded as well. In this case, the appropriate reduction factor must be entered. For completely unshaded surfaces, the factor is 1. This situation frequently occurs, especially with roof areas. Walls have shading factors of about 0.7 when surrounded by low-density buildings. In city centres, or if the roof overhang is relatively large, the factor is about 0.4. Because with well-insulated exterior surfaces the radiation balance is generally not very influential on the entire building, the reduction factor for shading does normally not have to be calculated in detail at this point. If necessary, the value can be calculated more accurately with the help of the **Windows** and **Shading** or **Shading-S** worksheets respectively.

7.6 Window Areas and Exterior Doors

Window areas are to be entered only in the **Windows** worksheet. It is recommended that all building components that consist primarily of glazing surfaces be entered as windows so that solar gains are accounted for. These areas are automatically carried over to the **Areas** worksheet and subtracted from the corresponding wall area. Five rows are reserved in the Area Input table for transfer of window areas in each of the cardinal directions, as well as horizontal placement.

For opaque exterior doors, a separate row in the **Areas** worksheet is provided. The total dimension and U-value of exterior doors with identical properties may be entered in the field provided.

Alternatively, U-values of opaque exterior doors with differing properties can be defined in the **U-values** worksheet. The doors are then addressed as other exterior wall building elements. In either case the door areas must be manually subtracted from their associated wall areas. For each relevant wall, the total area of the wall should first be entered, and then the area of the exterior doors should be calculated and entered in the **"User Subtraction" column**.

For glazed external doors it is recommended to enter the doors in the **Windows** worksheet and to take the solar gains into account.

7.7 Transfer of the Results

From the Summary section, the following information is automatically transferred to the rest of the PHPP file:

- Area Group
- Area for each member of the areas group
- Temperature zone
- Average U-value for each member of the areas group

7.8 Calculating the Treated Floor Area

Advice

All gains and losses, including the final result, refer to the treated floor area (TFA). Therefore, care must be taken to calculate the TFA correctly. A faulty calculation can lead to misleading results and could put certification in question.

The treated floor area is calculated based on the German Floor Area Ordinance (Wohnflächenverordnung [WoflV]). It refers to the part of the floor area that is inside the thermal envelope. The content of the "Wohnflächenverordnung" is briefly summarized below:

The floor area of a dwelling unit includes the floor area of all rooms that exclusively belong to this unit (with residential accommodations, hostels etc. the shared rooms are also included).

The floor area is determined using the clear width between building elements (e.g. plaster to plaster). The base areas of baseboards, non-detachable bath or shower tubs, built-in furniture etc. are part of the floor area.

Not part of the floor area are: chimneys, plumbing walls, columns etc. with a height exceeding 1.50 m and a base area of more than 0.1 m^2; stairs with more than three steps, and their landings; door and window niches (exception: windows that extend down to the floor and have a depth of more than 0.13 m). The area of floor openings, such as the open space in front of a loft or interior balcony, does not contribute to TFA.

The entire floor area of rooms and parts of rooms with a clear height of at least 2 m is used in deriving TFA. In areas of rooms, and parts of rooms, with a clear height between 1 and 2 m, the floor area is added with a 50 % utilization value, so only half of these areas counts towards TFA. Room areas with a lower height than 1 m are not included in the TFA derivation.

In the PHPP, only rooms inside the thermal envelope are taken into account. Greenhouses, terraces, exterior balconies, or other rooms that are located outside the thermal envelope are not included in the TFA.

Basements, secondary spaces such as mechanical rooms, or rooms that are not regarded as living space in the German "Wohnflächenverordnung", which are located inside of the thermal envelope and have a room height of at least 2 m, may be included in the treated floor area at a utilization value of 60 %.

In non-residential buildings, the treated floor area is made up of the portion of the net floor area that must be heated in order to be used. The net floor area is determined according to DIN 277-2. The main usable area of the building (Nutzfläche) is taken into account with 100 %. A utilization value of 60 % of the functional area (Funktionsfläche) and traffic area (Verkehrsfläche) inside of the thermal envelope is included in derivation of TFA. Stairs, elevators, and vertical service ducts are not included.

Table 2: Overview of Floor Area Utilization Factors for Non-Residential Buildings

Main Usable Area	Functional Area	Traffic Area
living space / occupied room office work production, manual and machine work experiments storage, distribution, selling education, cultural use healing and caring other usable areas	electrical and mechanical services	access and safe accessibility

Main Usable Area 100 %	Functional Area 60 %	Traffic Area 60 %
living and office rooms break rooms class rooms, group rooms storage rooms, wardrobes kitchens labs	building services (supply and disposal) electrical installations mechanical ventilation heating IT/communication ~~vertical service ducts~~	corridors ~~stairs~~ ~~elevator shafts~~

7.9 List of Thermal Bridges

The PHPP allows for complete consideration of all heat flows. The design principles of "Thermal Bridge-Free Construction" are highly recommended for Passive Houses. When these principles are adhered to, the supplementary heat flows through thermal bridges are so small that they can be omitted from the calculations [PHI 1995/5]. Often, the supplementary heat loss in some parts of the structure may be negative, resulting in less thermal loss than would be indicated without calculation of precise values. For linear thermal transmittance coefficients (Ψ) greater than 0.01 W/(mK), the losses from supplementary heat flows must be considered. It is up to the user whether to consider effects from remaining thermal bridges.

To consider impacts from thermal bridges, the linear thermal transmittance coefficient (Ψ) (with respect to the exterior reference dimensions) must be available. The thermal bridge inputs (lengths and heat loss coefficients) are to be entered in the **Areas** worksheet starting from row 143. The heat flows are then averaged in the top portion of the worksheet for each temperature zone. The respective total length and length-weighted average values are identified in rows 22 to 24 and automatically carried over to the heating balance in the **Annual Heat Demand** worksheet.

There is a tool for an auxiliary calculation of thermal bridge heat loss coefficients with reference to exterior dimensions from given interior reference dimensions (see **column X**).

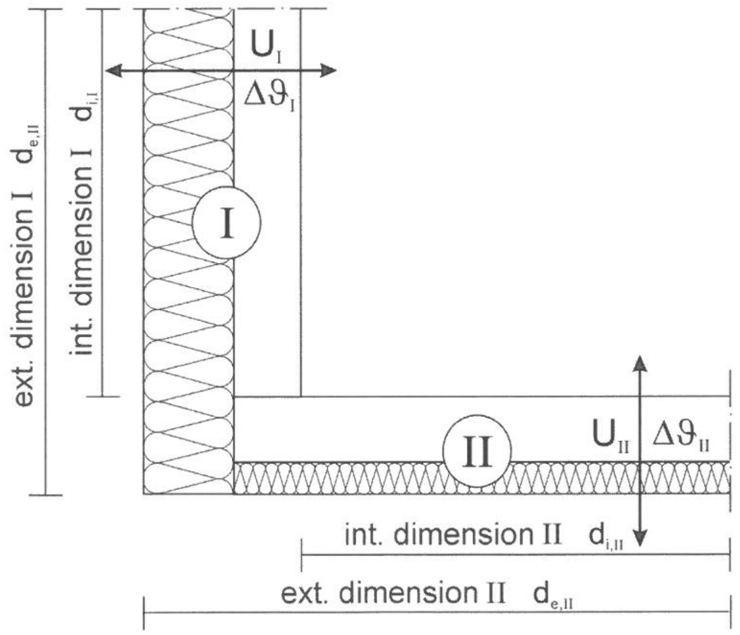


Figure 5: Thermal bridge dimensions for the converting from interior to exterior references

The relevant building element dimensions for the calculation can be taken as defined in Figure 5.

Note: When using "Thermal Bridge-Free Construction" (see the chapter on thermal bridges on page 97) there is no need to perform further calculations.

Validated, two-dimensional heat flow calculation programs are suitable for performing thermal bridge calculations. These programs provide realistic results using finite element or finite difference methods. Some examples of two-dimensional heat flow programs are THERM, HEAT2, Bisco, WinIso, AnTherm see also DIN 10211-1. These programs determine the total two-dimensional heat flow, Q_{2Dim}, using mathematical operations. The linear Ψ-value is calculated using:

$$\Psi = \frac{Q_{2Dim} - Q_{1Dim}}{\ell \cdot \Delta\vartheta}$$

Referenced to Exterior Dimensions

Q_{2Dim}: Heat flow, calculated using the numeric method

$\Delta\vartheta$: Temperature difference between the exterior and interior

$$Q_{1Dim} = \Sigma\, A_i \cdot U_i \cdot \Delta\vartheta_i$$

U_i: U-values of the building assemblies

A_i: Building element area number "i", (using exterior reference dimensions)

Architectural solutions with the lowest possible thermal bridge heat loss coefficients are preferred. Assistance for reduction of thermal bridges is contained in the publication "Thermal Bridge-Free Construction" and is available in German. [PHI 1995/5]

The additional conduction heat losses for the thermal bridges are automatically calculated in the PHPP using the following formula:

$$Q_T = \ell \cdot \Psi \cdot f_T \cdot G_t$$

ℓ: Thermal bridge length

Ψ: Linear thermal transmittance coefficient (evaluated using exterior dimensions)

f_T: Reduction factor (see Chapter 7.2.2)

G_t: Time integral of the temperature difference (heating degree hours)

Frequently, the most difficult thermal bridges to avoid are those for below-ground building elements. These thermal bridges are affected by the adjacent soil, so they must be handled differently than thermal bridges to ambient air. Further details on perimeter thermal bridges that are near or within the floor slab can be found in Chapter 10.6.

8 "U-List" Worksheet

This worksheet totals the U-values calculated in the **U-Values** sheet and allows you to generate a summary. This list can be completed by adding a database in the lower portion of the list. The description of the building element, the overall thickness, and the U-value, are linked directly from the **U-Values** worksheet. The **Areas** worksheet and the **U-Values** worksheet are linked. In **column "T"** (or **"U"** respectively) of the **Areas** worksheet, the building assemblies can be chosen, and the corresponding U-values are assigned from the U-List into the **Areas** worksheet.

Also the lower portion of the worksheet contains the U-values of typical building assemblies. The user can extend this part of the list by addition of further building assemblies to form a database.

The **U-List** worksheet in the PHPP 2007 lists sample building assemblies with PHI certified components from Line 29. The PHI will regularly publish updated lists on the PHI website (www.passiv.de).

Detached house in Templin, Germany
Photo: Hoffmann und Tollaas

9 "U-Values" Worksheet: Calculation of Building Element U-Values

This worksheet serves as a tool for calculating the overall heat transfer coefficients of the building elements (U-values). The U-value calculations in the PHPP comply with ISO 6946. The calculations are not suitable for building elements with metal penetrations.

The U-value of a construction assembly consisting of homogeneous layers of materials works out to

$$U = \frac{1}{R_{si} + R_1 + R_2 + \cdots + R_n + R_{se}} .$$

R_{si}, R_{se}: Thermal resistance at interior and exterior surfaces in compliance with ISO 6946. See Table 4.

$R_1 \ldots R_n$: Thermal resistance of individual construction layers, 1...n

In this worksheet, the thermal resistance of the individual construction layer "i" is calculated using the thickness and the thermal conductivity of the material: $R_i = d_i/\lambda_i$. A few thermal conductivities for important building materials are given in .

Table 3: A few thermal conductivities for important building materials. For wood and wood products, the thermal conductivity is to be multiplied by a factor of 2.2 when the heat flow is parallel to the direction of the fibres.

Material	**Thermal conductivity λ [W/(mK)]**
Concrete (Reinforced)	2.1
Lightweight Concrete	0.15–0.3
Rubber	0.17
Carpet	0.06
Linoleum	0.17
Float Glass	1
Aluminium	160
Mild Steel	50
Stainless Steel	17
Solid Plastic (Typical)	0.17–0.3
Gypsum Plaster	0.18–0.56
Gypsum Plasterboard	0.25
Cement Screed	1.4
Natural Stone	1.5–3.5
Sand-Lime Masonry	1
Softwood	0.13
Hardwood	0.18
Chipboard	0.1–0.18
Oriented Strand Board (OSB)	0.13
Wood Fibreboard, Medium Density Fibreboard (MDF)	0.07–0.18
Expanded Rigid Polystyrene Foam	0.035–0.04
Extruded Rigid Polystyrene Foam	0.030–0.04
Mineral Wool	0.035-0.045
Solid Clay Brick Masonry	0.8–1.2
Vertically Perforated Lightweight Block Masonry	0.3–0.45
Wood Wool Lightweight Building Board	0.065–0.09
Rigid Polyurethane Foam	0.025–0.04
Fibre Insulating Material	0.035–0.05
Cellular glass	0.045-0.06
Wooden Softboard	0.04–0.07

In some countries, e.g. the USA, due to the use of imperial units, λ-values are not customary. Instead, k-values are used. They signify the same physical quantity, but are measured in Btu•in/(ft²•hr•°F) or sometimes Btu/(ft•hr•°F). Conversion:

1 Btu•in/(ft²•hr•°F)	=	0.1442 W/(mK)
1 W/(mK)	=	6.9335 Btu•in/(ft²•hr•°F)
1 Btu/(ft•hr•°F)	=	1.730 W/(mK)
1 W/(mK)	=	0.578 Btu/(ft•hr•°F)

In practice, the thermal resistance of a material is often given by R-values per inch, which are the reciprocal of the k-values. Therefore, R-values per inch in $ft^2 \cdot hr \cdot °F/(Btu \cdot in)$ translate to thermal conductivities λ in W/(mK) via

$$\lambda = \mathbf{0.1442/R}$$

and vice versa.

The R-value per inch must not be confounded with the thermal resistance of a complete building element, e.g. a wall. The latter is also characterized by an R-value, in units of $hr \cdot ft^2 \cdot °F/Btu$. Conversion to metric thermal resistance RSI: 1 $hr \cdot ft^2 \cdot °F/Btu$ = 0.176 m^2K/W, 1 m^2K/W = 5.678 $hr \cdot ft^2 \cdot °F/Btu$. As the U-value is the reciprocal of the metric R-value, R-values of building elements in imperial units translate to U-values in $W/(m^2K)$ via

$$\mathbf{U = 5.678/R}$$

and vice versa. For example, a typical Passive House wall with U = 0.10 $W/(m^2K)$ is R-57.

The last worksheet of the English PHPP 2007 contains the most important conversions between imperial and SI units.

It is also possible to enter different thermal conductivities for a composite building element consisting of different materials, as in the case of a wood-framed wall. If you would like to avoid costly thermal bridge calculations, the thermal resistance of some composite building assemblies can be approximated by performing two different calculation methods simultaneously. The calculated results represent a lower and an upper limit for the effective heat loss (see ISO 6946 for the procedure).

Assembly No.	Building Assembly Description
1	Exterior wall

Heat Transfer Resistance [m^2K/W] interior R_{si}: 0.13

exterior R_{se}: 0.04

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Interior plaster	0.350					15
2.	Limestone masonry	1.100					175
3.	Polystyrene Foam	0.040					275
4.	Exterior Plaster	0.800					20
5.							
6.							
7.							
8.							

Percentage of Sec. 2:

Percentage of Sec. 3:

Total: 48.5 cm

U-Value: 0.138 $W/(m^2K)$

Enter the necessary values for the calculations in the **U-Values** worksheet.

If the building assembly has several layers, the data of Sections 2 and 3 need to be given only in those layers in which the conductivity in one section area differs from the other.

Enter the surface thermal resistances for every building element. An overview of various heat transfer resistances is given in . Heat transfer is considered horizontal if the heat flow is up to ±30° from the horizontal.

Table 4: Surface Thermal Resistances, "R", corresponding with EN ISO 6946. The value R_{se} = 0 must be used for calculations in the PHPP for below ground construction elements.

	Direction of Heat Flow		
	Upward	Horizontal	Downward
R_{si} [m²K/W]: Thermal Resistance of the Interior Surface	0.10	0.13	0.17
R_{se} [m²K/W]: Thermal Resistance of the Exterior Surface	0.04		
R_{se} [m²K/W]: Thermal Resistance of the Below Ground Exterior Surface	0		

The exterior facing adjacent to the air space would not be considered for the U-value calculation when well-ventilated air spaces exist in the exterior wall assembly (that means spaces with openings between air layer and exterior air exceeding 1500 mm². per m length for vertical air layers and 1500 mm² per m² of the surface for horizontal air layers). In these cases, for the thermal resistance of the exterior surface the same value as for interior surface may be used.

9.1 Still air spaces

Assistance for calculating the thermal conductivity for still air spaces is found to the right of the U-value calculations. Enter the thickness of the air space and the direction of the heat flow to determine the thermal conductivity of the air space.

Secondary calculation: Equivalent thermal conductivity of still air spaces

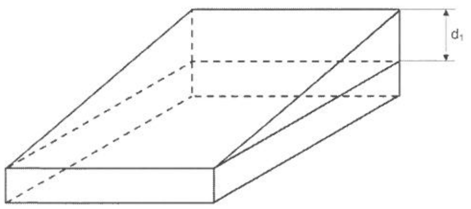
Air Layer Thickness	100	mm			λ	
Direction of		Upwards	h_a	1.25 W/(m²K)	0.542	W/(mK)
Heat Flow	x	Horizontal	h_r	4.17 W/(m²K)		
(check only one field)		Downwards				

Poorly ventilated air spaces (that means spaces with openings between air space and exterior air between 500 and 1500 mm² per m length for vertical air spaces and 500 and 1500 mm² per m² of the surface of horizontal air spaces) are calculated with a value that is twice that of the calculated thermal conductivity. A total thermal resistance less than or equal to 0.15 m²K/W may be used for the construction assemblies adjacent to the cold side of poorly ventilated air spaces.

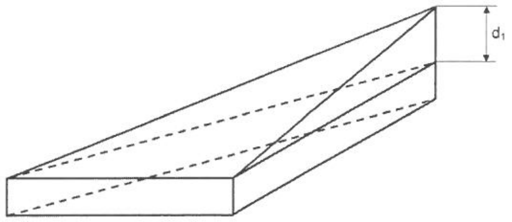
9.2 Wedge-Shaped Building Assemblies in Compliance with ISO 6946

The U-value calculation of wedge-shaped building assemblies can be performed using the tool on the right side of the main **U-Values** worksheet. It allows you to calculate e.g. sloping insulations in flat roof constructions. The slope is limited to 5 % in this procedure.

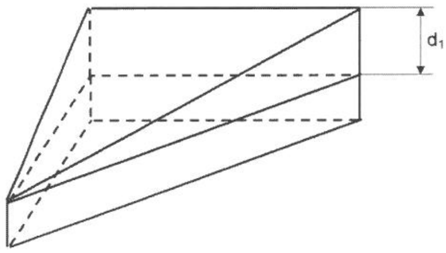
Enter all parallel building assemblies of the element in **Section A**. In **Section B**, enter the maximum thickness of wedge-shaped elements defined as d_1. Flat roof insulation is generally composed of rectangular or triangular sections. The corresponding U-value can be determined using the calculation on the right side of this worksheet. The U-values of the following shapes can be calculated using this tool:



Rectangular Based Wedge



Triangular-Base Wedge, maximum thickness at the apex



Triangular-Base Wedge, minimum thickness at the apex

The overall heat transfer coefficient of a roof assembly A is determined using,

$$U = \sum U_i \cdot A_i / A$$

9.3 Composite Building Elements

The overall heat transfer coefficient for composite assemblies is, in general, the average value of the minimum and maximum limits of the calculation. These boundaries also denote the extent of a possible error concerning the calculation of thermal resistance. If the error is greater than 10 %, differing from the standard, the PHPP will use the lower value of thermal resistances + 10 %. Normally this precaution ensures a factor of safety. In many cases, a thermal bridge calculation will reveal a more favourable U-value.

10 "Ground" Worksheet: Calculating the Heat Losses from Below-Ground Building Elements

This sheet calculates heat losses of below-ground building elements following the DIN EN ISO 13370 procedures. Using this sheet, heat losses through below-ground building elements can be calculated more accurately, by taking the building geometry into account, than what can be determined using overall reduction factors. The fact that, the larger the floor slab is the lower the heat losses are, due to the insulating effect of the soil, is taken into consideration. Seasonal ground storage effects are also included in the calculation.

If the **Ground** worksheet is not completed, the standard reduction factor determined in the **Climate Data** worksheet is used in the **Annual Heat Demand** worksheet. For the **Monthly Method** in this case the ground temperatures are calculated independent from the building's geometry based on the ambient temperatures.

The DIN EN ISO 13370 algorithms have been improved in several respects. Background information and further details about the calculation process for heat losses through the ground can be found in German in [AkkP 27].

The calculation method separates the heat flow into steady-state and harmonic components. The heat flows can be determined for four different situations:

- **Heated basement**: This type is also applicable to floor slabs that are partly or completely located below ground level. In this case, the below-ground portion of the exterior wall is entered as a basement wall.
- **Unheated basement**.
- **Slab on grade**: This type is applicable to evenly insulated floor slabs. The floor slabs can also have additional perimeter insulation.
- **Suspended floor:** This applies to above-ground ventilated crawl spaces.

When a building has several floor types, the reduction factors for each floor type should be calculated separately by inserting duplicate **Ground** worksheets, as required, to calculate factors for the additional types. The calculated reduction factors must then be inserted into the **Annual Heat Demand** worksheet.

For example, consider a heated basement adjacent to an unheated basement. Calculations for the heated basement should be performed on one **Ground** worksheet, ignoring the shared wall with the unheated basement. The shared wall should then be considered as a basement ceiling in the calculation of the heat losses to the unheated basement.

The relevant climate data is automatically shown when a climate data set is selected. The average ground surface temperature is approximately 1 K above the average ambient air temperature because of the positive solar radiation balance of the ground surface area. In regions with higher solar irradiation, high building density or deep snow the average ground surface temperature can be higher. If more detailed information is available, the formula can be altered correspondingly (unlock worksheet).

The ground surface temperature rises and falls over time as a sine wave that has an amplitude approximately half the difference between the maximum and minimum monthly average ambient temperatures. The calculation in the **Ground** worksheet is based upon the ground surface temperature instead of the ambient temperature. No exterior air film effect is present at this interface and the value $R_{se} = 0$ is used for the calculation of the U-values of building elements against the ground. The algorithms used here are based on a constant room temperature set point for the annual period.

Standard values are supplied as defaults for soil properties. These values should be revised when more accurate data are available. The following general values can be used:

Table 5: Heat conductivities and volume-specific heat capacities of different soil types.

Soil Type	Heat Conductivity λ [W/(mK)]	Volume Specific Heat Capacity ρc [MJ/(m³K)]
Silt / Clay	1.5	3
Peat	0.4	3
Dry Sand / Gravel	1.5	1.5
Wet Sand / Gravel, Moist Clay	2	2
Saturated Clay	3	3
Rock	3.5	2

Soil is not usually homogeneous. In this case, the property values of the soil at a depth of B'/2 (B' = characteristic floor slab dimension as calculated in the **Ground** worksheet) should be entered. A higher heat conductivity of the soil must be calculated when groundwater is present.

10.1 Required Building Information

A: Floor slab area (exterior dimensions). The areas of exterior walls in contact with ground, e.g. as occurs with a heated basement, are not included in the floor slab area.

P: Floor Slab Perimeter: The perimeter lengths bordering heated rooms are excluded. For townhouses, for example, only the exterior lengths are included.

U_f: Floor Slab U-value (R_{se} = 0 for building elements adjacent to the ground). In cases of unheated basements or ventilated crawl spaces, enter the U-value of the basement ceiling.

To select the floor slab type, mark one of the four fields with an "x". Additional entries are then required depending on the selected floor slab type.

10.2 Heated Basement or Underground Floor Slab

z: Basement Depth: average distance from the ground surface to the bottom of the basement floor slab.

U_{wB}: U-Value Belowground Wall: average U-value of the basement wall (R_{se} = 0).

10.3 Unheated Basement

The above entries are required for an unheated basement as well as for a heated basement. For an unheated basement, the following information is also required:

n: Air Change Unheated Basement: air exchange rate in the unheated basement. A typical value is 0.2 h^{-1}.

V: Basement Volume: air volume of the unheated basement. The basement ventilation heat losses are calculated based on this volume and the air exchange rate.

h: Height Aboveground Wall: average height of the aboveground portion of the exterior basement wall.

U_W: U-Value Aboveground Wall: average U-value of the aboveground portion of the exterior basement wall.

U_{fB}: U-Value Basement Floor Slab: average U-value of the basement floor slab.

10.4 Perimeter Insulation for Slab on Grade

No further entries are necessary for slabs on grade. However, the calculation method allows for inclusion of perimeter insulation. This is additional insulation at the floor slab edge that is small in extent compared to the width of the floor slab (see Figure 6). For well-insulated Passive House floor slabs, only a small proportion of heat losses through the floor slab can be reduced by using perimeter insulation. Even so, multidimensional simulations have shown that the simplified calculation method in the PHPP underestimates the heat conservation due to perimeter insulation. In some situations a thermal bridge calculation may be useful.

The U-value of the floor slab, U_f, is to be initially calculated before considering the perimeter insulation. If both vertical and horizontal perimeter insulation is used, only the one that results in smaller heat loss is considered.

The following values are necessary to calculate the effect of perimeter insulation on heat losses:

D: Width (for horizontal perimeter insulation); or depth (for vertical perimeter insulation).

d_n: Thickness of perimeter insulation.

λ_n: Thermal conductivity of perimeter insulation.

Additionally, it must be specified whether the perimeter insulation is vertical or horizontal. Using the same dimensions, vertical perimeter insulation proves to be the more effective technique.

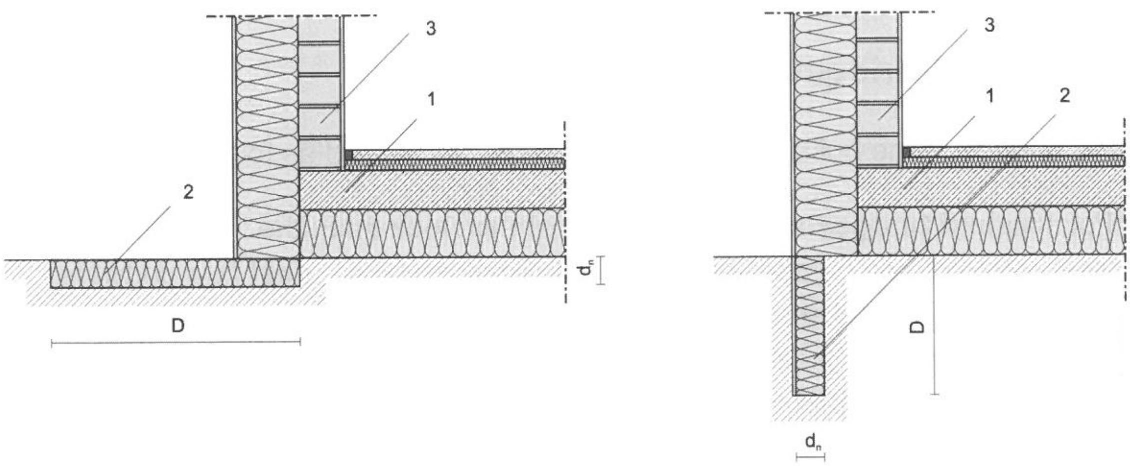


Figure 6: Horizontal (left) and vertical (right) perimeter floor slab insulation on grade with corresponding dimensions. 1 - Floor Slab, 2 - Perimeter Insulation, 3 - Exterior Wall.

10.5 Suspended Floor

For Central and Northern European climate zones, practical experience has shown that suspended floors above minimally ventilated crawlspaces tend to be problematic. For this reason the PHI recommends against such building practices. In spite of this, for reasons of completeness, the algorithms for modelling these constructs is included in the PHPP.

Values for the crawl space under the actual floor slab are to be entered here. The exterior walls and the floor of this space can be insulated:

U_{Crawl}: U-value of the floor under the crawl space. If the ground is not insulated, the heat transfer coefficient of (5.9 W/(m^{2}K)) must be used.

h: Average height of the crawl space walls.

U_W: Average U-value of the crawl space walls.

εP: Total area of the ventilation openings of the crawl space.

v: Average wind velocity at 10 m height in the selected location.

f_W: Wind shield factor. This value can be taken from the following table:

Building Site	**f_W**
Protected Site, e.g. City Centre	0.02
Average Site, e.g. City Suburb	0.05
Exposed Site, e.g. Rural Area	0.10

10.6 Thermal Bridges

Thermal bridges at the building foundation can be considered as follows:

- **For thermal bridges at the perimeter of the floor slab**, the linear thermal transmittance can be calculated using thermal modelling heat flow software. The software model should contain the thermal bridge for the building elements together with the adjacent ground. The calculation will provide a steady-state value for heat flow that is determined in reference to the temperature difference between interior and ambient air (or surface area adjacent to the ground). An additional dynamic computation derives the harmonic relationship, amplitude and phase shift, between ambient temperature and heat loss. To reduce calculation costs the dynamic calculation can be omitted, and the same value can be used for both harmonic and steady-state situations. In order to use this simplified approach, the additional heat losses through the thermal bridges must remain smaller than the heat losses which would have been present had the bridging components not been present; for Passive Houses, this is usually the case. The steady-state thermal bridge heat loss coefficients of the perimeter thermal bridges are to be entered in the **Areas** worksheet. If harmonic thermal bridge heat loss coefficients have been calculated, the results are to be entered in the **Ground** worksheet.

- **For thermal bridges in the middle of the floor slab**, (e.g. load bearing interior walls that penetrate the insulation layer), the Ψ–Value can be determined through a heat flow program as well. The surrounding ground need not be considered in this calculation. The Ψ–Value and corresponding length are to be entered in the **Areas** worksheet.
- **For the ceilings of unheated basements**, the calculation is performed in the same manner. At the junction of basement ceiling and exterior wall, the calculation results in two thermal bridge heat loss coefficients: between interior and exterior, and between interior and basement. The first value must be entered as a thermal bridge against ambient air, and the second as a thermal bridge at the floor slab.

The treatment of thermal bridges in below-ground building elements and the determination of the thermal bridge heat loss coefficients are described in detail in [AkkP 27]. The publication is available in German from the PHI.

Note: Even though the Ψ–Values of perimeter thermal bridges are calculated with the temperature difference to the outside air, for reasons of clarity they are used in calculations in the **Annual Heat Demand** and **Monthly Method** worksheets with the same reduction factors and heating degree hours as the other heat losses to the ground. The overall results remain valid since the reduction factor and the equivalent ground temperatures are specified accordingly in the **Ground** worksheet.

10.7 Ground Water

There is no need to consider groundwater in most cases. Heat losses to groundwater become important if the groundwater depth is less than 3 m and water flow velocities are greater than 0.2 m/d. For some of these conditions, correction factors are given in DIN EN ISO 13370. These factors were originally calculated for an above ground floor slab. The PHI has developed a user-friendly estimation formula that is an interpolation between those factors. Until more standard methods are available, we also recommend using this approach for basements.

Two values need to be entered:

z_W: The depth of the groundwater table beneath the building (under the basement floor for basements). When the basement floor is below groundwater level, negative values can also be entered; however, these results can only be considered as a rough estimation of the groundwater impact.

q_W: Groundwater flow velocity. The filtration velocity is to be entered here, i.e. the average quantity of water that flows through a square meter during the day. **Caution:** The actual water velocity, $v_a = q_W/n_{eff}$, is frequently used for hydrology (n_{eff} is the usable interstitial portion in the ground). The usable interstice can amount to only 1 % of the volume, so confusing the two values would deliver overly conservative results.

10.8 Results

The result of the **Ground** worksheet is made up of three parts. The first result is the reduction factor to ground used in the annual method. If very low reduction factors are calculated, a warning message appears in the worksheet. The calculation should then be carefully checked: Is the modelled building area actually surrounded by relatively well-insulating ground material? Are there really neither groundwater flows nor convective undercurrents beneath the floor slab, or something similar?

The second result provides the average ground temperatures used in the monthly method calculation for the heat demand and the useful cooling demand. The differences between summer and winter data result from the different indoor temperatures.

The third result is the design temperature used for the calculation of the heat and cooling loads.

Montessori school in Aufkirchen, Germany
Photo: Gernot Vallentin

Passive House Planning

HEAT LOSSES VIA THE GROUND

Ground Characteristics			
Thermal Conductivity	λ	2.0	W/(mK)
Heat Capacity	ρc	2.0	MJ/(m³K)
Periodic Penetration Depth	δ	3.17	m

Climate Data			
Av. Indoor Temp. Winter	T_i	20.0	°C
Av. Indoor Temp. Summer	T_i	25.0	°C
Average Ground Surface Temperature	$T_{g,ave}$	10.0	°C
Amplitude of $T_{g,ave}$	$T_{g,\wedge}$	8.6	°C
Length of the Heating Period	n	7.4	months
Heating Degree Hours - Exterior	G_t	84.0	kKh/a

Building Data			
Floor Slab Area	A	80.9	m²
Floor Slab Perimeter	P	25.0	m
Characteristic Dimension of Floor Slab	B'	6.47	m

Floor Slab U-Value	U_f	0.131	W/(m²K)
Thermal Bridges at Floor Slab	Ψ_B*l	0.70	W/K
Floor Slab U-Value incl. Thermal Bridges	U_f'	0.139	W/(m²K)
Eq. Thickness Floor	d_t	14.3	m

Floor Slab Type (select only one)	
	Heated Basement or Underground Floor Slab
	Slab on Grade
x	Unheated basement
	Raised Floor Slab

For Basement or Underground Floor Slab			
Basement Depth	z	2.39	m
Additionally for Unheated Basements			
Air Change Unheated Basement	n	0.20	h⁻¹
Basement Volume	V	120	m³

U-Value Belowground Wall	U_{wB}	0.600	W/(m²K)
Height of the Aboveground Foundation Wall	h	0.00	m
U-Value Aboveground Wall	U_W	0.138	W/(m²K)
U-Value Basement Floor Slab	U_{fB}	0.645	W/(m²K)

For Perimeter Insulation for Slab on Grade			
Perimeter Insulation Width/Depth	D		m
Perimeter Insulation Thickness	d_n		m
Thermal Conductivity of the Perimeter Insulation	λ_n		W/(mK)
Location of the Perimeter Insulation	horizontal		
(check only one field)	vertical	x	

For Raised Floor Slab			
U-Value Crawl Space	U_{Crawl}		W/(m²K)
Height of Crawl Space Wall	h		m
U-Value Crawl Space Wall	U_W		W/(m²K)
Area of Ventilation Openings	εP		m²
Wind Velocity at 10 m Height	v	4.0	m/s
Wind Shield factor	f_W	0.05	-

Additional Thermal Bridge Heat Losses at Perimeter			
Phase Shift	β		months
Steady-state Fraction	$\Psi_{P,stat}$*l	0.000	W/K
Harmonic Fraction	$\Psi_{P,harm}$*l	0.000	W/K

Groundwater Correction			
Depth of the Groundwater Table	z_W	3.0	m
Groundwater Flow Rate	q_W	0.05	m/d
Groundwater Correction Factor	G_W	1.0338692	-
Thermal Transmittance Below-Ground El. (Without Ground)	L_{reg}	88.03	W/K
Relative Insulation Standard	d_t/B'	0.28	-
Relative Groundwater Depth	z_W/B'	0.46	-
Relative Groundwater Velocity	l/B'	0.13	-

Basement or Underground Floor Slab			
Eq. Thickness Floor Slab	d_t	3.1	m
U-Value Floor Slab	U_{bf}	0.28	W/(m²K)
Eq. Thickness Basement Wall	d_w	3.33	m
U-Value Wall	U_{bw}	0.37	W/(m²K)
Steady-state Transmittance	L_S	46.69	W/K
Phase Shift	β		months
Exterior Periodic Transmittance	L_{pe}	19.22	W/K

Unheated Basement			
Steady-state Transmittance	L_S	9.35	W/K
Phase Shift	β	1.20	months
Exterior Periodic Transmittance	L_{pe}	2.83	W/K

Slab on Grade			
Heat Transfer Coefficient	U_0		W/(m²K)
Eq. Ins. Thickness Perimeter Ins.	d'		m
Perimeter Insulation Correction	$\Delta\Psi$		W/(mK)
Steady-state Transmittance	L_S		W/K
Phase Shift	β		months
Exterior Periodic Transmittance	L_{pe}		W/K

Raised Floor Slab Above a Ventilated Crawl Space (at max. 0.5 m Below Ground)			
Eq. Ins. Thickness Crawl Space	d_g		m
U-Value Crawl Space Floor Slab	U_g		W/(m²K)
U-Value Crawl Space Wall & Ventilation	U_X		W/(m²K)
Steady-state Transmittance	L_S		W/K
Phase Shift	β		months
Exterior Periodic Transmittance	L_{pe}		W/K

Interim Results			
Phase Shift	β	1.20	months
Steady-state Transmittance	L_S	9.35	W/K
Exterior Periodic Transmittance	L_{pe}	2.83	W/K
Steady-state Heat Flow	Φ_{stat}	93.2	W
Periodic Heat Flow	Φ_{harm}	9.5	W
Heat Losses During Heating Period	Q_{tot}	554	kWh

Ground Reduction Factor for "Annual Heat Demand" Worksheet 0.585

Monthly Average Ground Temperatures for Monthly Method

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average Value
Winter	10.0	9.6	9.8	10.5	11.5	12.6	13.5	13.9	13.7	13.0	12.0	10.9	11.7
Summer	10.9	10.4	10.6	11.3	12.4	13.5	14.3	14.7	14.6	13.9	12.8	11.7	12.6

Design Ground Temperature for the Heat Load Worksheet 9.6 **for Cooling Load worksheet** 14.7

11 "Windows" Worksheet: Window Area Calculations, Window U-Values and Orientation-Dependent Solar Radiation

The heat losses and gains of the windows have a great impact on the energy balance of a Passive House, and therefore have to be calculated very carefully.

Window areas, window U-values, solar radiation through glazing, and the corresponding reduction factors can be determined with this worksheet. Window data is to be entered, beginning from Line 23.

The relevant data are summarized in the upper part of the **Windows** worksheet and are automatically inserted into the corresponding worksheets.

11.1 Solar Radiation and Window Direction

Calculations with dynamic building simulations have shown that the orientation-dependent global radiation roughly follows a trigonometric function. This function only depends upon the angular deviation from a reference direction and the angle of the inclination.

North is used as the reference direction. All angles are measured in the clockwise direction relative to North.

The "deviation from North" ϕ, is measured as an angle in the horizontal plane between the North-South axis and the horizontal projection of an imaginary light beam perpendicular to the window.

Detached model house in Alzenau, Germany
Photo: Hebel Haus

Some ϕ-values are listed as a reference in the following table.

North	0°
Northeast	45°
East	90°
Southeast	135°
South	180°
Southwest	225°
West	270°
Northwest	315°

Table 6: Angular deviation ϕ from the North-South line.

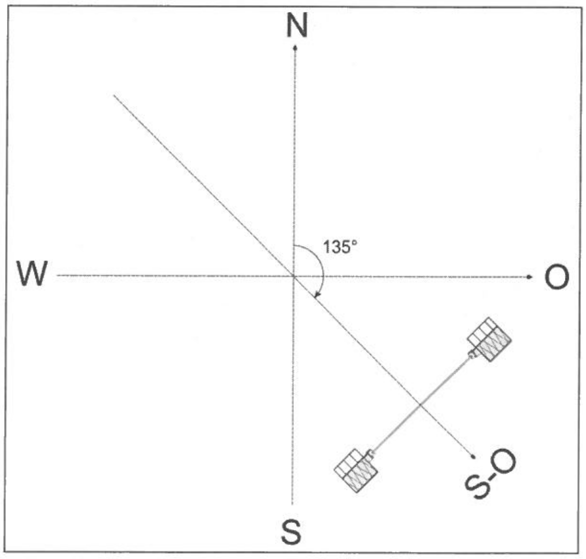


Table 7: Definition of the angular deviation.

The angle of inclination is also required for the calculation of total radiation. It describes the angle between the normal to the window surface and the zenith. Thus, a vertically installed window has a Θ-value of 90°. For a window in a flat roof, the value would be Θ = 0°.

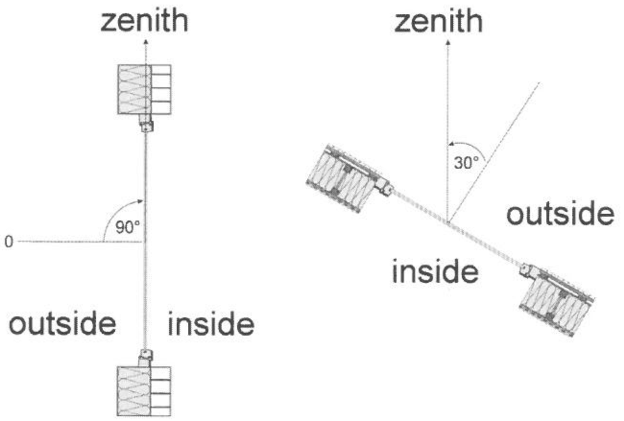


Figure 8: Definition of the angle of inclination, Θ

The solar irradiation for each window is automatically calculated in the **Windows** worksheet from the entries ϕ and Θ. A general orientation (North, East, South, West, or horizontal) is automatically assigned for each window and the average global radiation value of all windows of the same orientation is given in the cells "Average Global Radiation". These average values are automatically carried over into corresponding worksheets.

Quantity	Description	Deviation from North	Angle of Inclination from the Horizontal	Orientation
		Degrees	Degrees	
4	South Ground Floor	180	90	South
4	South Upper Floor	180	90	South
4	South Attic	180	90	South
2	North Ground Floor	0	90	North
1	West	270	90	West
2	North Upper Floor	0	90	North

Climate:	Standard										
Window Area Orientation	Global Radiation (Cardinal Points)	Shading	Dirt	Non-perpendicular Incident Radiation	Glazing Fraction	g-Value	Reduction Factor for Solar Radiation	Window Area	Window U-Value	Glazing Area	Average Global Radiation
maximum:	kWh/(m²a)	0.75	0.95	0.85				m²	W/(m²K)	m²	kWh/(m²a)
North	140	0.89	0.95	0.85	0.644	0.50	0.46	11.04	0.77	7.1	140
East	220	0.75	0.95	0.85	0.000	0.00	0.00	0.00	0.00	0.0	220
South	370	0.84	0.95	0.85	0.655	0.50	0.44	30.42	0.78	19.9	370
West	230	0.82	0.95	0.85	0.604	0.50	0.40	2.00	0.80	1.2	230
Horizontal	360	0.75	0.95	0.85	0.000	0.00	0.00	0.00	0.00	0.0	360
		Total or Average Value for All Windows.				0.50	0.45	43.46	0.78	28.2	

Global Solar Radiation per Cardinal Point

Average Global Solar Radiation for All Assigned Windows

11.2 Local Solar Radiation Data

If local climate data are used, the radiation data for each general orientation will automatically be derived and adopted by the **Windows** worksheet.

11.3 Window Data Entries

Number: Similar windows can be entered together. Please note that windows of the same dimension can differ in their shading characteristics. If this is the case an individual entry for each is suggested.

! Advice

Entering additional rows in the middle of the windows worksheet frequently leads to faulty links in one of the Windows, Shading or Shading-S worksheets that are not easily noticeable. When necessary only insert rows at the end of the table and pay strict attention to the instructions in chapter 2.5.6.

An unambiguous identifier for the window, for instance the use of position numbers, has been proven to be useful. Unique identification aids communication between all involved persons and the calculations are easier to understand.

Window dimensions: For the height and width of the windows always use the dimension of the rough openings.

Window Glazing and Frame U-value, g-value: With the high quality of contemporary triple-pane low emissivity glazing, a correspondingly high quality window frame is necessary to maintain a comfortable indoor climate and favourable energy balance, especially during the winter months. In the last few years a wide variety of insulated window frame designs have been developed.

Thanks to innovative window manufacturers, a selection of Passive House suitable windows with super-insulated frames is available on the market. The certificate 'Component suitable for Passive Houses: Window Frame' is issued when the *Passive House Institute* approves these products. The certificate contains the specifications of the window components necessary to complete the calculations. A list of window manufacturers offering windows suitable for Passive Houses is available at the *Passive House Institute* (www.passiv.de).

In the PHPP, the thermal performance values of certified products (glazing and window frames) are found in the **WinType** worksheet. In the **Windows** worksheet, these values can be chosen from the pull-down selection menus (**columns "J"** and **"L"**).

The description field of the windows may not be completely visible in the selection menus. To avoid mistakenly using a wrong window, note the numbers at the right side of the selection window which correspond to the assembly number in the **WinType** worksheet.

Please note the advice about the use of the **WinType** worksheet, as well as the hints on using the selection menus in the chapter 2.5.7.

11.4 Window Installation

The amount of heat loss is highly dependent upon the quality of the window installation. In the column "**Installed**", the corresponding building element (wall, roof or floor construction) in which the respective window is installed is indicated. From the drop-down menu, the appropriate building element from the list in the **Areas** worksheet can be chosen. Alternatively you can enter the corresponding number at the right side of the selection menu.

In the PHPP, individual windows are differentiated from windows that are mulled against each other . The length of the installed edges has an important influence on the window U-value, therefore it must be determined as accurately as possible. Abutting windows have installed heads and sills. The shared jamb has no contact with the exterior building envelope. To calculate the length of the window heads and sills precisely, an installation factor was introduced (columns "U" to "X"). The installation factor is "1" if the corresponding jamb has direct contact with the building envelope. It is "0" if two windows are abutted symmetrically against each other.

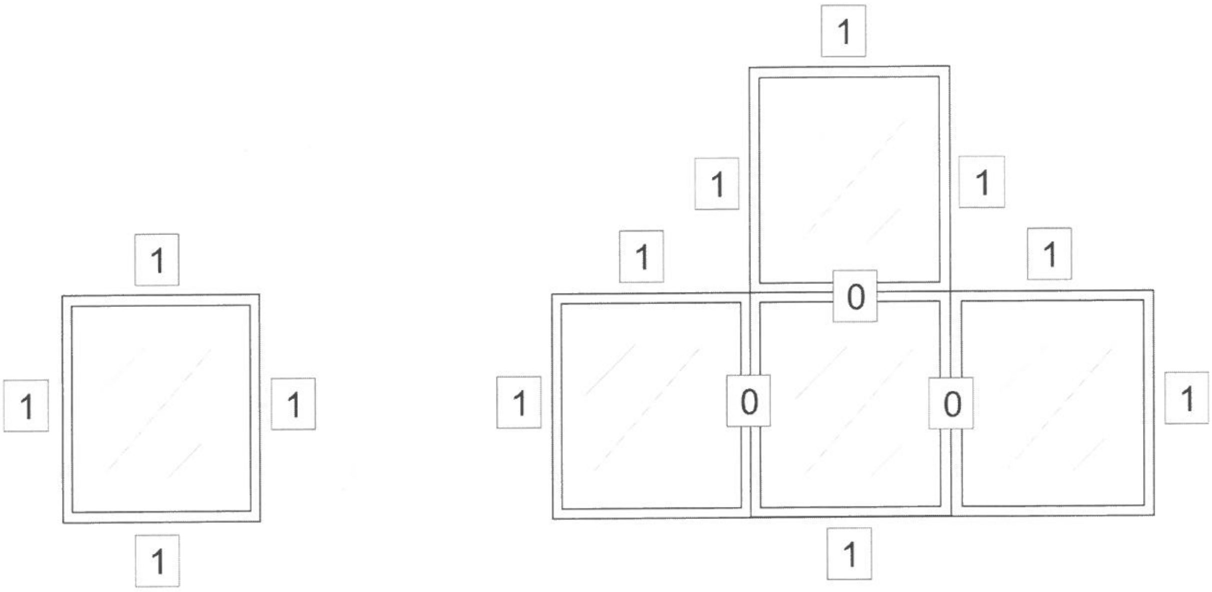


Figure 9: Abutted windows with installation factors.

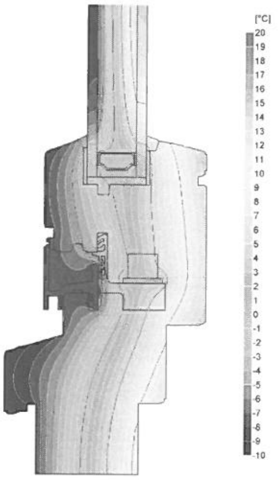
The window does not only consist of glazing and frame but also has a connection to the façade, and the glazing itself has a spacer. These junctions cause thermal bridge effects and are therefore the weakest thermal points of the window. Thermal bridge effects can be reduced by ensuring optimal installation and using an insulating spacer. The thermal bridge effect is described by the thermal bridge heat loss coefficients, $\Psi_{Installation}$, and Ψ_{Spacer}.

The spacer is the primary cause of thermal bridging at the glass edge seal. This problem can be reduced by using a window with an insulating spacer.

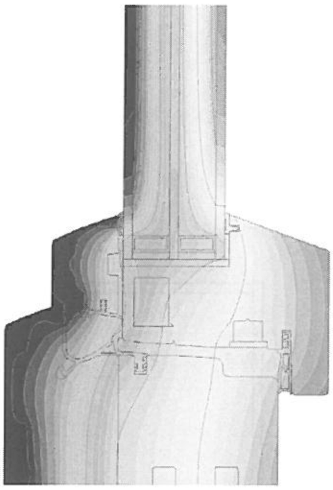
The thermal bridge effect is clearly illustrated in the following isothermal diagrams (Figure 10). The second illustration shows a window frame for Passive Houses (insulated wood-aluminium frame) with aluminium spacers, and the third with an insulating plastic spacer.

Heat loss through the thermal bridge caused by the two aluminium strips of 0.5 mm thickness and 1 m length is equivalent to the losses through 15.5 m^2 of undisturbed space between the glass panes. This example clearly illustrates the importance of taking the extra losses of the window spacer into account when calculating the thermal bridge effects of windows.

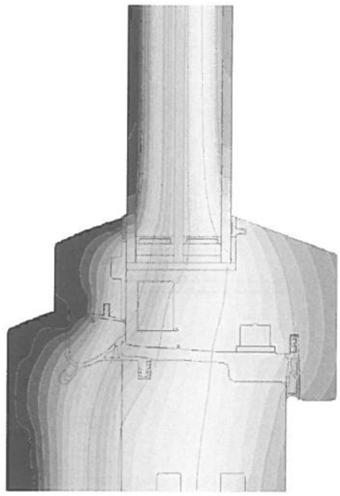
The value for Ψ_{Spacer} is documented in the PHI Certificate of Approval as well. The values for Ψ_{Spacer} are listed in the updated table of the **WinType** worksheet. The installation geometry is highly dependent on the individual project. Typical values can be found in the **WinType** worksheet as well.



Wood Window Frame "IV68" (ϑ_{min} = 7 °C)



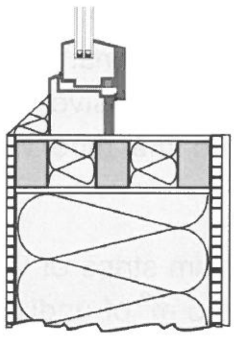
Passive House Window Frame with Aluminium Spacer (ϑ_{min} = 9.1 °C)



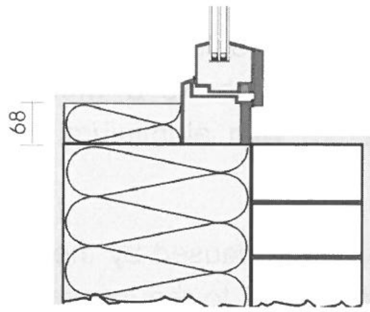
Passive House Window Frame with Insulated Spacer . (ϑ_{min} = 12.8 °C)

Figure 10: Isothermal diagram and surface temperatures with and without an insulating spacer in comparison with a 68 mm wood frame window "IV68".

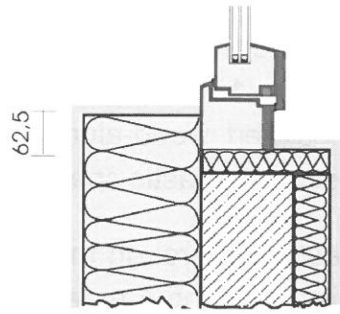
The following figure shows recommended details for window installations. Figure 12 shows some cross section details with their corresponding approximate thermal bridge heat loss coefficients at the windowsill, head and jambs. The values for wood-frame construction are only valid if no additional wood blocking has been used for the window installation. More precise values for $\Psi_{Installation}$ may be obtained using supporting information from the certification documents.



Window in Lightweight Wood Frame Wall



Window in Masonry / Concrete Wall



Window in Insulating Concrete Form Wall System

Figure 11: Installations suitable for Passive Houses: Concept sketches. See [Feist 1998].

! Advice

If you want to enter different installation Ψ-values, i.e. for head and reveal, you can use the following trick: Set the $\Psi_{Installation}$ in the **WinType** worksheet to 1 and enter instead of 1 or 0, the applicable Ψ-value for the installation factor in the **Windows** worksheet.

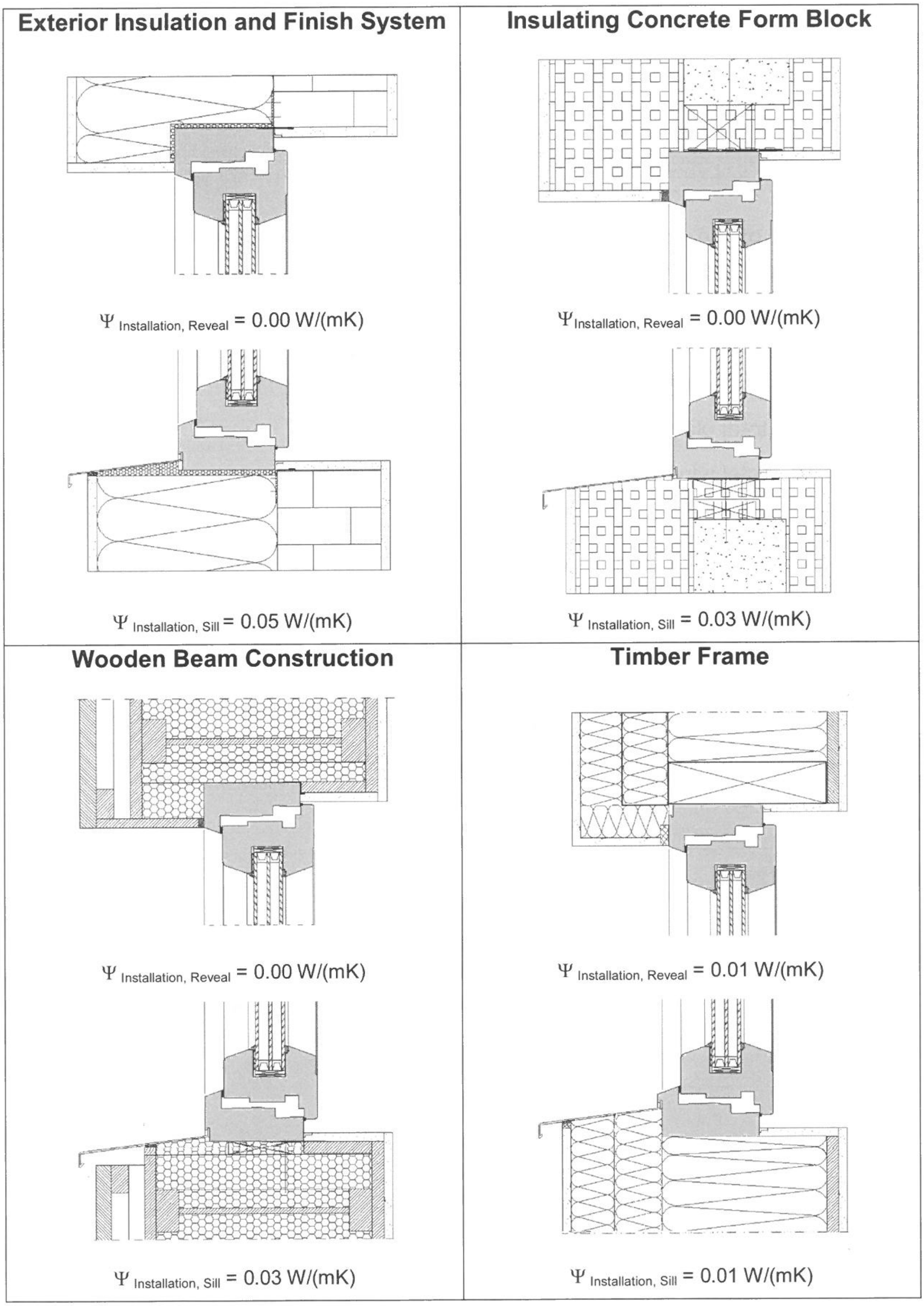


Figure 12: Installation examples and corresponding approximate thermal bridge heat loss coefficients for Passive House suitable windows.

Window Rough Openings		Installed		Glazing		Frame		g-Value	U-Value		Window Frame Dimensions				Installation				Ψ-Value	
Width	Height	in Area in the Areas worksheet	Nr.	Select glazing from the WinTyp worksheet	Nr.	Select window from the WinTyp worksheet	Nr.	Perpen-dicular Radiation	Glazing	Frames	Width - Left	Width - Right	Width - Below	Width - Above	Left 1/0	Right 1/0	Para-pet 1/0	Lintel 1/0	Ψ_{Spacer}	$\Psi_{Installation}$
m	m	Select:		Select:		Select:		-	W/(m²K)	W/(m²K)	m	m	m	m					W/(mK)	W/(mK)
1.100	2.120	Exterior wall so	1	Triple-low-e Kr0	1	standard PU on	1	0.50	0.70	0.59	0.14	0.14	0.18	0.14	1	0	1	1	0.049	0.005
1.140	2.120	Exterior wall so	1	Triple-low-e Kr0	1	standard PU on	1	0.50	0.70	0.59	0.14	0.14	0.18	0.14	1	0	1	1	0.049	0.005
1.120	2.550	Exterior wall so	1	Triple-low-e Kr0	1	standard PU on	1	0.50	0.70	0.59	0.14	0.14	0.18	0.14	1	0	1	1	0.049	0.005
1.200	2.300	Exterior wall no	2	Triple-low-e Kr0	1	wide PU on woc	3	0.50	0.70	0.59	0.15	0.15	0.18	0.15	1	0	1	1	0.049	0.005
0.910	2.200	Exterior wall we	3	Triple-low-e Kr0	1	standard PU on	1	0.50	0.70	0.59	0.14	0.14	0.18	0.14	1	1	1	1	0.049	0.005
1.200	2.300	Exterior wall no	2	Triple-low-e Kr0	1	wide PU on woc	3	0.50	0.70	0.59	0.15	0.15	0.18	0.15	1	0	1	1	0.049	0.005
			0		0		0													

The U-value of the window is calculated based on the quality of the glazing, the frame, the glass edge and the installation:

$$U_{Window} = 1/A_{Window} \cdot [U_{Glazing} \cdot A_{Glazing} + U_{Frame} \cdot A_{Frame} + \ell_{Glazing} \cdot \Psi_{Spacer} + \ell_{Frame} \cdot \Psi_{Installation}]$$

A_{Window}: total window area (rough opening)

$A_{Glazing}$: total glazing area

A_{Frame}: total window frame area

$U_{Glazing}$: glazing U-value

U_{Frame}: window frame U-value

$\ell_{Glazing}$: glazing perimeter

ℓ_{Frame}: window frame perimeter (installation edge)

Ψ_{Spacer}: thermal bridge heat loss coefficient of the glazing edge seal

$\Psi_{Installation}$: thermal bridge heat loss coefficient of the installation

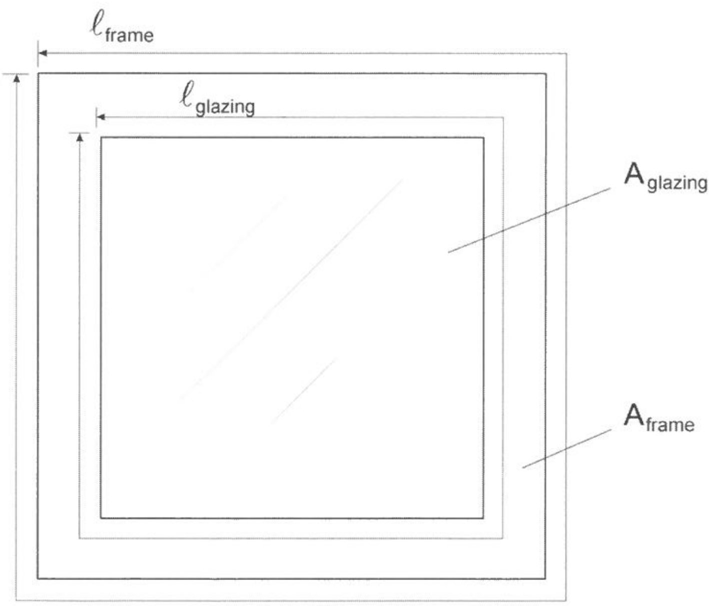


Figure 13: Dimensions for the window U-value calculation.

11.5 Reduction Factors for Solar Gains

The reduction factor, "r", is calculated with the following formula:

$$r = r_{Shading} \cdot r_{Dirt} \cdot r_{Incidence\ Angle} \cdot r_{Frame}$$

$r_{Shading}$: Reduction factor considering the degree of shading from neighbouring buildings, trees, overhangs, etc. Standard value: 0.75. The shading factor can be specified more precisely in the **Shading** worksheet.

r_{Dirt}: Reduction factor to account for dirty windows. Standard value = 0.95.

$r_{Incidence\ Angle}$: Reduction factor accounting for the reduced energy transmittance due to non-perpendicular radiation. Standard value = 0.85.

r_{Frame}: Reduction factor accounting for the area of the window frame.

The reduction factors are calculated in the **Windows** and **Shading** worksheets respectively, and are summarized at the top of the **Windows** sheet in columns "D" to "G." The result is the reduction factor in column "J", which is automatically carried over to the **Heating Load** worksheet.

Climate:	Standard						
Window Area Orientation	Global Radiation (Cardinal Points)	Shading	Dirt	Non-perpendicular Incident Radiation	Glazing Fraction	g-Value	Reduction Factor for Solar Radiation
maximum:	kWh/(m²a)	0.75	0.95	0.85			
North	140	0.89	0.95	0.85	0.644	0.50	0.46
East	220	0.75	0.95	0.85	0.000	0.00	0.00
South	370	0.84	0.95	0.85	0.655	0.50	0.44
West	230	0.82	0.95	0.85	0.604	0.50	0.40
Horizontal	360	0.75	0.95	0.85	0.000	0.00	0.00
		Total or Average Value for All Windows.				0.50	0.45

12 "WinType" Worksheet

The **WinType** worksheet contains the data for window glazing and frames. The frames are listed in the lower part of the table. The table contains the following information:

- glazing designations
- glazing g-values (SHGC)
- glazing U_g-values
- window frame designations
- window frame dimensions (dimensions of the frame in elevation: sill, head and jamb)
- U_f-value of the window frame (average values of sill, head, and jamb)
- thermal bridge heat loss coefficient of the spacer, Ψ_{Spacer}
- thermal bridge heat loss coefficient of the installation, $\Psi_{Installation}$

The lists are referenced in the **Windows** worksheet. In this sheet, window frames and glazing types can be selected and the corresponding data entered into the appropriate columns. At the top of the list (with yellow background) data of user-defined frames can be entered or data can be copied from the lists below into the yellow cells. This is necessary when e.g. the frame dimensions have to be modified because two windows abut each other (approx. adjustment for freestanding posts).

A standard thermal bridge heat loss coefficient, $\Psi_{Installation}$, of 0.04 W/mK has been entered for every listed and certified window frame.

! Advice

The standard value for $\Psi_{Installation}$ is relatively pessimistic. Please pay attention to a thermal bridge optimized window installation and enter the corresponding value, as described below. This can result in the heat demand being lowered significantly.

There is an additional list of thermal bridge heat loss coefficients at the bottom of the **WinType** worksheet. The thermal bridge heat loss coefficients for various installations have been calculated for different types of window frames (wood, PVC, wood/aluminium.) Please choose the appropriate $\Psi_{Installation}$-value for your project. The best method is to combine the values of the desired frame with the appropriate $\Psi_{Installation}$-value. This project specific combination can then be entered into the yellow cells at the top of the frame type list. Please note that the given values for $\Psi_{Installation}$ can only act as guidelines. Be critical and verify the applicability to your project. The manufacturers of the certified products may be able to provide values that are more precise. If you doubt the suitability of the window installation data for your project, it is advisable to have a two-dimensional thermal bridge calculation performed.

At the top of each list values are given for conventional glazing, uninsulated window frames, and uninsulated installation configurations, to assist the user in assessing preexisting buildings.

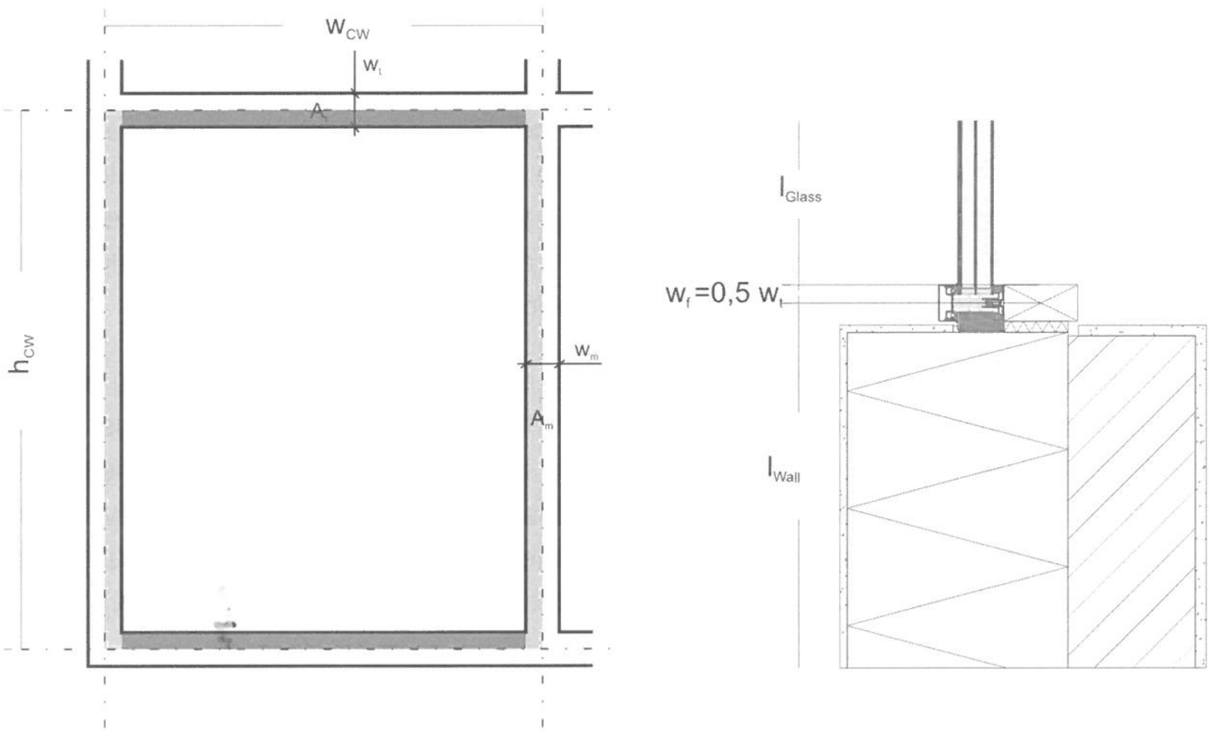


Figure 14: Elevation and section of a mullion and transom façade; only half of the frame width is considered for each individual module.

Mullion and transom façades differ from windows with respect to size, arrangement and installation situations. Due to these differences, a separate certificate for Passive-House-suitable mullion and transom façades is available. The following points should be noted:

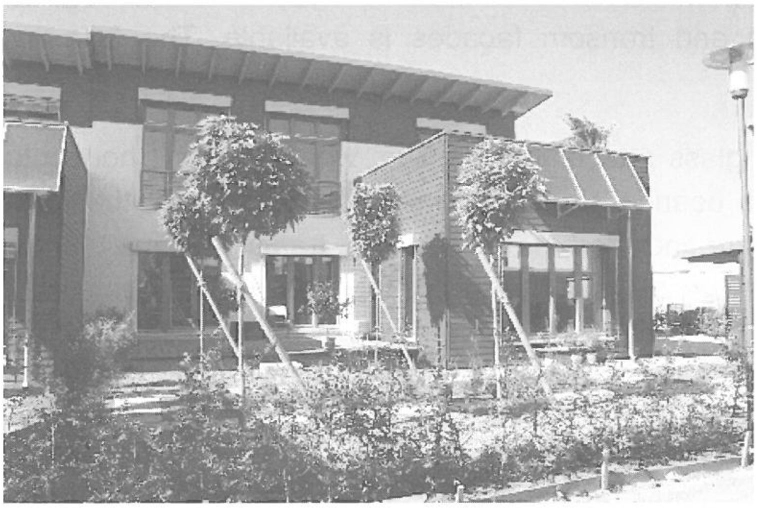
Screws are used to attach the glass attachment profiles, which transmit horizontal forces from the glazing into the bearing structure. Due to these screws, there are additional heat losses which are included as ΔU in the frame U-value. In the "WinType" worksheet the frame-U-value must be given together with the screws. If there are no values available for their influence, ΔU must be estimated as 0.3 W/(m²K).

The vertical loads of the glazing are transmitted via the glass carriers into the bearing structures. The glass carriers also cause additional heat losses which must be taken into account by the punctiform thermal bridge χ_{GC}, which is entered in the "Areas" sheet with the number of glass carriers as a punctiform thermal bridge (by entering the value in the "Ψ W/(mK)" column, length = 1). Generally, each pane of glass is held by two glass carriers. If there are no values available for the influence of the glass carriers, χ_{GC} must be estimated to be 0.04 W/K. If the material of the glass carriers is known, the following values can be set:

- metal glass carrier: χ_{GC} = 0.040 W/K
- non-metallic glass carrier with screws: χ_{GC} = 0.004 W/K
- non-metallic glass carrier: χ_{GC} = 0.003 W/K

Generally, a mullion and transom façade consists of many modules arranged above and next to each other. If only one module is considered, which is surrounded on all sides by other modules, only half of the frame width "belongs" to the module in the middle, the other half is considered to belong to one of the modules adjacent to it. For this reason the frame widths in mullion and transom façades are taken into account with only half of the actual measurements (Figure 14).

This is different for ending modules which, for example, are connected to a wall on one or more sides. Here, the second half of the frame width also belongs to the module, and is taken into account with the installation thermal bridge heat loss coefficient, which is therefore higher than that of windows. For assembly of the mullion and transom façade in the insulation level, if the installation thermal bridge loss coefficient is not known, it can be estimated to be $\Psi_{Installation}$ = 0.07 W/(mK).



Terraced houses in Erlangen, Germany
Photo: Nouri Schellinger

13 "Shading" Worksheet

The **Shading** worksheet calculates a total Shading Factor (r_S) for glazing surfaces, during heating periods (see **Shading-S** Worksheet for Summer periods), derived by the following formula:

$r_S = r_H * r_R * r_O * r_{ot}$

where r_S equals the total Shading Factor and where:

r_H: Horizontal Obstruction Shading Factor, continuous horizontal obstruction in front of the window, e.g. a row of similar height buildings (see Section 13.1).

r_R: Vertical (Reveal) Shading Factor, vertical elements on the side(s) of the window, e.g. fins and reveals (see Section 0).

r_O: Horizontal (Overhang) Shading Factor, horizontal elements that cantilever out above the window, e.g. overhangs and balconies (see Section 13.3).

r_{other}: Additional Shading Factors (see Section 13.4).

Each factor indicates the percentage of solar radiation reaching the glazing surface as reduced by the respective shading element. A shading factor of 100 % means the window is unshaded; a shading factor of 0 % means the window is completely shaded. The total Shading Factor (r_S) is derived on the Shading worksheet for each respective row on the **Windows** worksheet by multiplying the individual shading factors.

Notes:

- Algorithms used in the above shading factor formula were derived from building simulation.
- The shading factor algorithms utilize window and building geometry and orientation entered on the Windows worksheet. The calculation also considers the time of year and encompasses the heating period only.
- Total Shading Factors for each orientation are automatically calculated and inserted into the Windows worksheet.

13.1 Horizontal Obstruction Shading Factor (r_H)

The factor r_H accounts for a continuous horizontal obstruction located in front of a window as, for example, a row of houses. Since this factor assumes a continuous extended obstruction it will return a conservative (lower) shading percentage for Townhouses, single semi-detached, and single-detached houses. However, if the distance between the horizontal obstruction and the window is less than about 10 m, the overestimation of shading effect will be slight, even for the non-continuous obstructions mentioned above.

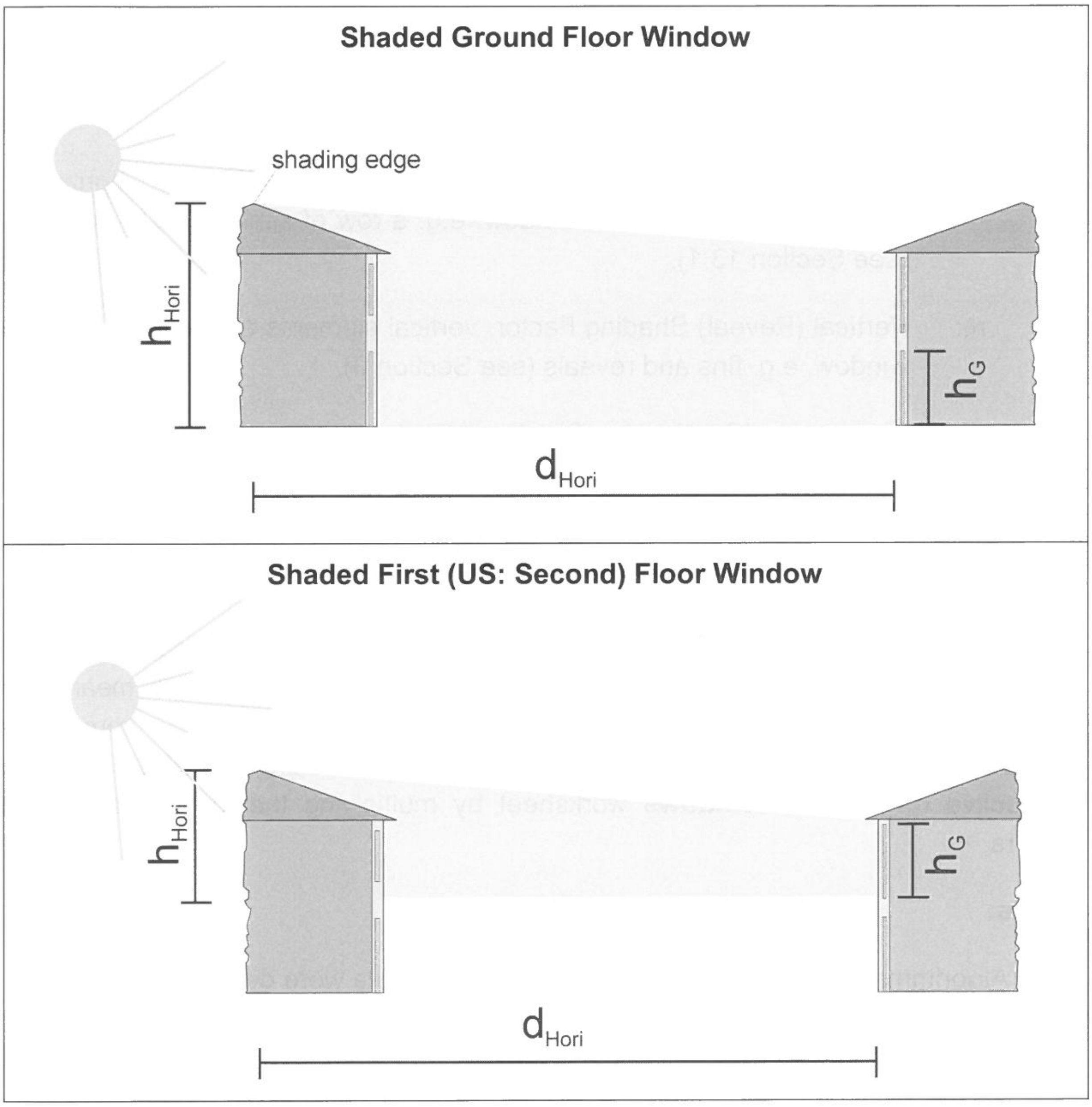


Figure 15: Shading by a row of houses

h_G: Height of the transparent window area

h_{Hori}: Height of the shading object measured from the bottom edge of the shaded glazing area to the highest point of the shading object
Note: The h_{Hori} value for windows on different floors may vary.

a_{Hori}: Horizontal distance between the transparent window and the highest point of the shading object

13.2 Vertical Shading Factor (r_R)

The factor r_R accounts for the shading effect of an exterior vertical element such as the side reveal of a window casing, a vertical shading element such as a fin or louver, or a projecting lateral building wall. For window casing the reveal depth is measured from the exterior wall to the glazing surface (see Figure 16).

o_{reveal}: projected depth of window reveal from the wall surface to the glazing surface

d_{reveal}: average frame width for the side of the window from wall surface to glazing edge

In the event that the primary shading element is a vertical fin or wall projection measurements to these surfaces should be used as appropriate for the above values.

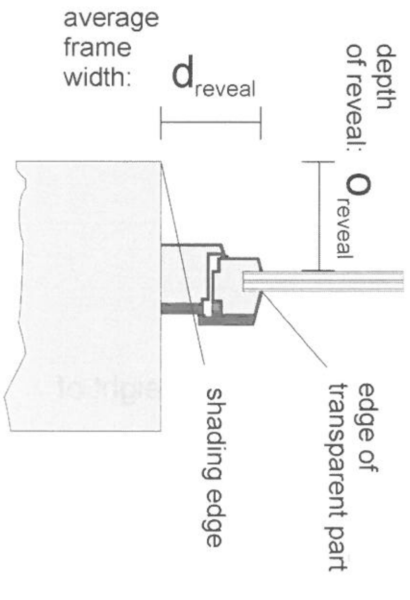


Figure 16: Shading by a window reveal (horizontal section)

Note: Mullioned casement windows have a much larger distance to the reveal on the mullioned side than the wall side. In this case an averaged value should be used for the distance to the reveal.

Glazing height and width pre-entered in the **Windows** worksheet are automatically copied to the **Shading** and **Shading-S** worksheets and only affect the Shading Factor. If an unusual window or shading condition exists, the user can adapt the worksheet's calculation method by turning off the worksheet's write protection and modifying glazing height and width.

13.3 Horizontal Shading Factor (r_O), e.g. Balcony Slab or Lintel

The factor r_O accounts for the shading effect of an exterior horizontal element such as an overhang or balcony slab. If these elements are not present or not decisive values must be entered for window lintel, since shading from overhead elements is not evaluated by the r_R calculations.

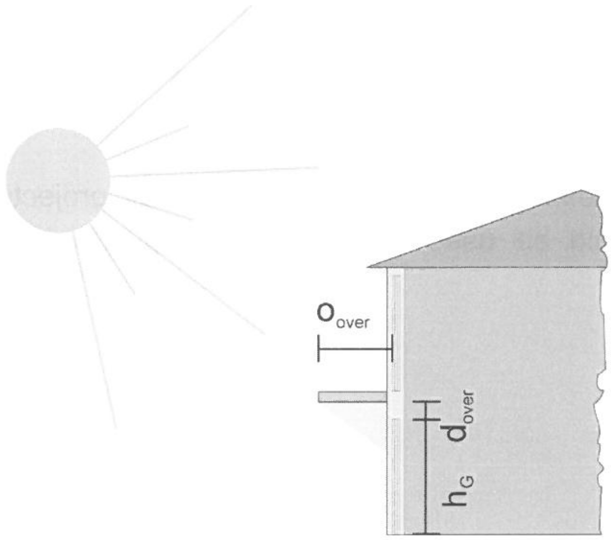


Figure 17: Shading by an overhang

o_{over}: Overhang length measured from the exterior glass surface

d_{over}: Distance of the overhang from the upper glass edge, typically the height of the window lintel plus the width of the window frame

h_G: Glazing height

13.4 Additional Shading Factor (r_A)

The user can define an additional shading factor (r_{other}) in the last column of user-defined inputs that follows h_{hor}, d_{hor}, o_{over}, d_{over}, o_{reveal} and d_{reveal}. The additional shading factor may used to describe a balcony railing, mesh screen or window gate. If the value is left empty for this cell, the worksheet assumes a value of 100 % that means no additional shading is contributed to the total Shading Factor (r_S).

! Advice

In order to estimate additional shading factors for building elements which can not be described using the three standard shading elements it is typically possible to build a composite representation using the built in algorithms provided by the PHPP. Utilization of special tools to more accurately calculate specific shading situations is not typically justified, and usually has low impact on energy balance results.

Passive House Planning

CALCULATING SHADING FACTORS

Climate: Standard

Building: End-of-Terrace Passive House Kranichstein

Latitude: 51.3 °

Orien-tation	Glazing Area	Reduction Factor
	m²	r_S
North	7.11	89%
East	0.00	100%
South	19.92	84%
West	1.21	82%
Horizontal	0.00	100%

Quantity	Description	Deviation from North	Angle of Inclination from the Horizontal	Orientation	Glazing Width	Glazing Height	Glazing Area	Height of the Shading Object	Horizontal Distance	Window Reveal Depth	Distance from Glazing Edge to Reveal	Overhang Depth	Distance from Upper Glazing Edge to Overhang	Additional Shading Reduction Factor	Horizontal Shading Reduction Factor	Reveal Shading Reduction Factor	Overhang Shading Reduction Factor	Total Shading Reduction Factor
		Degrees	Degrees		m	m		m	m	m	m	m	m	%	%	%	%	%
					w_G	h_G	A_G	h_{Hori}	d_{Hori}	o_{Reveal}	d_{Reveal}	o_{over}	d_{over}	r_{other}	r_H	r_R	r_O	r_S
4	S Ground Fl.	180	90	South	0.83	1.81	6.0	10.80	42.50	0.16	0.135	0.43	0.55		87%	94%	96%	79%
4	S Upper Fl.	180	90	South	0.87	1.81	6.3	8.30	42.50	0.16	0.098	0.43	0.55		92%	94%	96%	83%
4	S Attic	180	90	South	0.85	2.24	7.6	5.80	42.50	0.16	0.135	0.43	0.55		96%	94%	97%	88%
2	N Ground Fl.	0	90	North	0.90	1.98	3.6	0.00	0.00	0.16	0.150	0.16	0.15		100%	92%	96%	89%
1	West	270	90	West	0.64	1.89	1.2	0.00	0.00	0.16	0.135	0.16	0.14		100%	86%	96%	82%
2	N Upper Fl.	0	90	North	0.90	1.98	3.6	0.00	0.00	0.16	0.150	0.16	0.15		100%	92%	96%	89%

14 "Ventilation" Worksheet: Sizing the Ventilation System

The required air exchange rates for supply and extract air volumes and the specific demands of the building ventilation system are determined in this worksheet.

14.1 General Planning Instructions

Based on practical experience with ventilation systems, the following points are emphasized:

- Coming from the usual practice in non-residential buildings, air flow volumes that are too high are occasionally dimensioned for Passive Houses. Sometimes the systems are also being run on an air change rate, which is to high. Apart from the resulting additional demand for heat and ventilation electricity the indoor air then tends to get to dry.
- When selecting a ventilation system, special attention should be paid to an economic running mode, that means a low specific electric energy consumption. The system is to be optimised for the most frequently occurring air change rate and not for the maximum rate.
- Attention should be paid to the correct dimensioning of the flow-off vents between the supply-air and the extract-air zones (pressure loss max. 1 Pa) [Pfluger 1999].
- The insulation of cold air duct segments in a heated room has to be executed in a diffusion-tight way in order to prevent the accumulation of condensation water on the surfaces of the air ducts underneath the insulation.

Especially when running the ventilation system intermittently, as it frequently occurs in non-residential buildings, attention has to be paid to the following aspects:

- When determining the average air change rate of a ventilation system, which is run in interrupted mode, besides the expected ventilation mode a flushing period prior to beginning of the use must be taken into account. The ventilation heat losses, which are smaller than if the systems runs permanently and the reduced demand for auxiliary electric energy will be accounted for in the balance through the average air change rate. The ventilation periods will generally be controlled by a weekly time schedule. In the **Ventilation** worksheet the weekly average values of the daily running times using the appropriate ventilation levels are entered
- *Filter Drying*: Turning off the ventilation when the moisture content of the fresh air filter is relatively high can lead to filter problems. Necessary measures (according to [VDI 6022]) must be taken to ensure that moisture does not

continuously penetrate the filter pad (for more info in German, see *Strategien zur Trocknung* in the *Protokollband AkkP 33* article *Luftqualität in Schulen*).

In the course of the initial start-up an adjustment of the mechanical systems, especially of the ventilation system is absolutely necessary. Occasionally devices have been installed without an initial start-up. In such cases a correct functioning is virtually impossible. During the initial adjustment the air flow volumes for the individual rooms according to the planning are set and the balancing of the system is carried out. The following instructions should be obeyed:

- At first the outdoor air and the exhaust air are balanced (in the air duct with permanently installed wings and pressure difference measurements or at the outdoor air intake / exhaust air outlet with a funnel for measuring air flow volumes, respectively)
- At the supply air outlet valves and the extract air intake valves the planned air flow volumes can then be adjusted.
- The adjustment of the balance has to be repeated, if necessary (iterative process) until the balanced condition has been reached (max. deviation +/- 10 %)
- An adjustment of the balance by measurements at the supply air and extract air valves only is not recommended, because of its poor accuracy. The adjustment of balance should always be carried out at the outdoor air / exhaust air side.
- An exact adjustment can only be achieved if the system and the air duct network is airtight. Systems in apartment buildings have to be examined for airtightness e.g. if the supply air and extract air ducts are located in the same installation duct und the extract air is under low pressure.

14.2 Air Change

The **supply air demand** results from the requirements of the DIN 1946 Part 6 (30 $m^3/(h \cdot Person)$). In schools and day-care centres 15 to 20 m^3/h per child have proven to be sufficient. The exact dimensioning depends on the age of the children and the type of use (all-day school or school from approx. 8 a.m. to lunchtime). Gyms need a ventilation of 60 m^3/h because of the higher degree of activity of the users.

For determining the **extract air demand** enter the number of the individual extract air rooms. More categories can be added (for example smoker's room: 40 m^3/h). The extract air demand results from the minimum value according to DIN 1946 for these extract air rooms.

The **design airflow rate** has to be dimensioned, to cover at least the calculated extract air and supply air demand. The average air change rate is calculated by multiplication with the factor 0.77 (residential use) or according to the secondary calculation (office buildings, seminar rooms, etc.), respectively. The average air change rate should not fall below 0.3 h^{-1} for reasons of indoor air hygiene. On the other hand it should not be too high, so that the indoor air does not get to dry during the heating period. In the yellow field "design air flow rate" a formula is included. As the result a corresponding layout is suggested. The planner can deviate from this value in justified cases. In this case the new design value is to be entered here.

The air exchange volume for the ventilation system is determined by the following formula:

$$n_{V,System} = \frac{V_{average\ air\ flow}}{V_V}$$

$V_{average\ air\ flow}$: hourly air flow rate [m³/h] = average volume of air exchanged

V_V: reference volume for the mechanical ventilation system (occupied area x room height)

Depending on the desired ventilation operation scheme, (the number of hours per day with minimal / normal ventilation demands; or basic ventilation with peak demands, respectively), the air exchange rate is determined and transferred into the heat balance of the **Annual Heat Demand** worksheet. If no inputs are entered in the **Ventilation** Worksheet, a standard value of 0.4 h^{-1} is used.

Passive House Planning

VENTILATION DATA

Building: End-of-Terrace Passive House Kranichstein

Treated Floor Area A_{TFA}	m²	156	*(Areas worksheet)*
Room Height h	m	2.5	*(Annual Heat Demand worksheet)*
Room Ventilation Volume (A_{TFA}*h) =V_V	m³	390	*(Annual Heat Demand worksheet)*

Ventilation System Design - Standard Operation

Occupancy	m²/P	35				
Number of Occupants	P	4.5				
Supply Air per Person	m³/(P*h)	30				
Supply Air Requirement	m³/h	**134**				
Extract Air Rooms		Kitchen	Bathroom	Shower	WC	
Quantity		1	1	1	1	
Extract Air Requirement per Room	m³/h	60	40	20	20	
Total Extract Air Requirement	m³/h	**140**				
Design Air Flow Rate (Maximum)	m³/h	152				

Average Air Change Rate Calculation

Type of Operation	Daily Operation Duration h/d	Factors Referenced to Maximum	Air Flow Rate m³/h	Air Change Rate 1/h
Maximum		1.00	152	0.39
Standard	24.0	0.77	117	0.30
Basic		0.54	82	0.21
Minimum		0.40	61	0.16
x Residential Building		**Average value** 0.77	Average Air Flow Rate (m³/h) **117**	Average Air Change Rate (1/h) **0.30**

14.3 Infiltration

The infiltration air change caused by leaks is determined according to EN 13790. For balanced ventilation systems with heat recovery it is calculated using:

$$n_{V,Res} = n_{50} \cdot e \cdot \frac{V_{n50}}{V_V}$$

n_{50}: Fan pressurization test result

e: Wind screening coefficient according to EN 832, values as listed in the table in this worksheet.

V_{n50}: Net air volume – reference volume for the fan pressurization test

			for Annual Demand:	for Heat Load:		
Wind Protection Coefficient, e			0.07	**0.18**		
Wind Protection Coefficient, f			15	**15**	Net Air Volume for Press. Test	V_{n50}
Air Change Rate at Press. Test	n_{50}	1/h	0.22	0.22	480	m³
Type of Ventilation System						
x Balanced PH Ventilation	*Please Check*		for Annual Demand:	for Heat Load:		
Pure Extract Air						
Excess Extract Air		1/h	0.00	0.00		
Infiltration Air Change Rate	$n_{V,Res}$	1/h	**0.019**	**0.047**		

Table 8: Wind Screening Coefficient in accordance with EN 13789.

Wind Screening Coefficients e and f in Accordance with EN 13789		
Screening Class Coefficient e	Several Sides Exposed	One Side Exposed
No Screening	0.10	0.03
Average Screening	0.07	0.02
High Screening	0.04	0.01
Coefficient f	15	20

The rate of air leakage, $n_{V,Res}$, is applied automatically in the **Annual Heat Demand** worksheet. If an air leakage test has not yet been performed, a standard value of 0.042 h^{-1} is applied. This value results from a 50 Pa fan pressurization test result of 0.6 h^{-1}, the highest air leakage rate permitted for Passive Houses. Please note, that the air exchange volume V_V must not necessarily equal the reference volume V_{n50}. The correction of the difference between the volumes is included in the V_{n50}/V_V factor.

Calculations determining the heating load are performed considering the worst-case scenario, assuming higher wind velocities and higher air leakage rates. Thus, the rate of air leakage is multiplied by a factor of 2.5. This value is applied automatically in the **Annual Heat Demand** sheet.

The **air tightness of buildings** is measured by installing a fan in an exterior door or window that applies high or low pressure to the entire building. The air volume, which is conveyed at this pressure and therefore flows through the leaks, is measured. This determines the remaining leakage. The pressurization test has to be carried out at various pressure differences for low and high pressure. The result of the pressurization test is the average air change rate n_{50} at 50 Pa pressure difference.

Requirement for Passive Houses: $n_{50} \leq 0.6\ h^{-1}$

This value has to be regarded as an upper limit. You should strive for lower values. The n_{50}-value is to be entered in the **Ventilation** worksheet (row: "air change rate of pressurization test")

Lobbies of public buildings are used intensively. The frequent opening of the entrance doors leads to an additional air change, which can potentially increase the heat losses during the heating period by a relevant amount. According to research at the entrance area of a primary school, however, the additional ventilation heat loss that can be expected is not relevant even for Passive House buildings [Kah 2007]. For buildings with a very frequent use of the entrance doors, e.g. supermarkets, branch banks etc, the additional infiltration should be taken into account.

For the estimation of the additional infiltration in buildings with other uses an air volume of 1.5 m^3 to 4.5 m^3 per person and event can be used. The smaller value is appropriate for entrances with porch and door closers, the higher value can be used for entrances without porch but with door closers. Entrance doors that open automatically (for example handicapped-accessible doors) may have a strongly reduced sluice effect of the porch, because of the delay times in the closing of the doors.

14.4 Heat recovery

14.4.1 Efficiency of Heat Recovery of Ventilation Systems

$\eta_{eff,HR}$ is the efficiency of heat recovery of the ventilation unit. This value describes the percentage of heat recovered from the extract air. It is an average value of measured test results which also takes into consideration the waste heat produced by the fan, heat losses from the central unit, and heat losses from induced infiltration. Test and analysis criteria can be provided by the PHI.

In the **Ventilation** worksheet the specifications of the certified units are listed. The corresponding unit can be selected using the menu.

Current German accreditation testing procedures for mechanical ventilation systems often produce unrealistically positive test results. If reliable measured values are not available, or a certificate is not presented, then the values are calculated by subtracting 12 % from accreditation test results.

An η_{eff}-value of 75 % can be used to calculate the efficiency of a counterflow heat exchanger in situations where accurate technical data are not available.

Cross-flow heat exchangers have lower efficiencies. A value no higher than 50 % can be used without more detailed measurements.

14.4.2 Calculating the Actual Efficiency of Heat Recovery

Duct runs should be well insulated and as short as possible. The high-efficiency ventilation unit can be installed either inside or outside the thermal envelope. However, it should remain as close as possible to the opening within the envelope because the heat losses from or to the ducts have serious implications for the efficiency of heat recovery.

If a balanced Passive House ventilation system is used, the installation location is to be selected by entering an "x" in the appropriate cells. The type and thickness of the insulation of duct sections from the central unit to the insulated thermal envelope can be individually entered in the secondary calculation. The duct lengths can differ depending upon the type of installation.

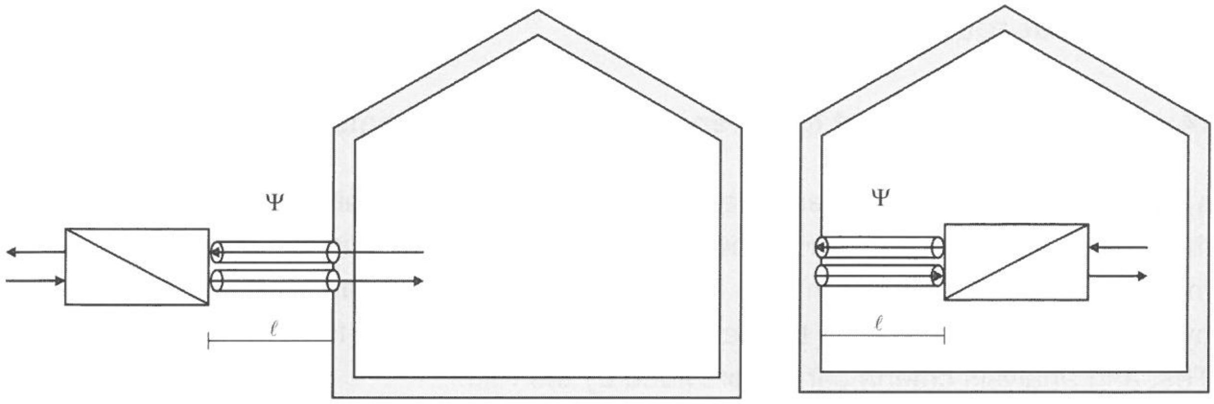


Figure 18: Diagrams showing central unit placed outside and inside the thermal building envelope.

If installing the HRV outside the thermally insulated envelope, the temperature of the installation room must be entered. Alternatively, if the room with the HRV is ventilated (e.g. an open basement or a ventilated attic), the ambient temperature must be inputted into the worksheet. A link between cells can be formed between the right-hand cell with the average ambient temperature and the cell with the room temperature of the HRV installation.

Effective Heat Recovery Efficiency of the Ventilation System with Heat Recovery

x	Central unit within the thermal envelope.
	Central unit outside of the thermal envelope.

Efficiency of Heat Recovery	η_{HR}		0.83	Heat Recovery Unit		
Transmittance Ambient Air Duct	Ψ	W/(mK)	0.166	Calculation see Secondary Calculation		
Length Ambient Air Duct		m	1.1			
Transmittance Exhaust Air Duct	Ψ	W/(mK)	0.228	Calculation see Secondary Calculation		
Length Exhaust Air Duct		m	1.5		Room Temperature (°C)	20
Temperature of Mechanical Services Room		°C	11		Av. Ambient Temp. Heating P. (°C)	4.0
(Enter only if the central unit is outside of the thermal envelope.)					Av. Ground Temp (°C)	10.0

Effective Heat Recovery Efficiency	$\eta_{HR,eff}$	**82.0%**

14.4.3 $\eta_{HR,eff}$ Using Multiple Heat Recovery Devices in One Building

In multi-unit housing or apartment buildings with multiple ventilation systems, the effective efficiency of heat recovery, $\eta_{HR,\,eff,\,i}$ must be calculated individually for each ventilation system within the **Ventilation** sheet (n = number of units). The weighted average of airflow, $\eta_{HR,eff}$, for all heat recovery devices can be calculated using the following formula:

$$\eta_{HR,eff} = \frac{\sum_{i=1}^{n} V_{Vi} \cdot n_{Vi} \cdot \eta_{HR,eff,\,i}}{\sum_{i=1}^{n} V_{Vi} \cdot n_{Vi}}$$

This value is then inserted into the main **Ventilation** worksheet.

The air flow rates (V_{Vi} n_{Vi}) are the respective average volume flows of each individual device.

14.5 Subsoil Heat Exchanger

For subsoil heat exchangers it is necessary to enter the efficiency η^*_{SHX}, which determines which percentage of the difference in the temperature of the outdoor air and the annual average temperature of the ground is compensated for by the subsoil heat exchanger. Factors of fundamental influence are the heat exchanging surface and the ground temperature around the SHX. Therefore, it is recommended to place the buried ducts as deep as possible and to maximize the length of duct runs. Figure 19 shows recommended installations and the related η_{SHX}-factor. An accurate calculation of the η_{SHX}-Factor is possible with the program PHLuft (in German). Download free of charge is possible at the PHI website: www.passiv.de. Optionally, horizontal or vertical ground loops of smaller diameters filled with a freeze resistant liquid can be used to extract the heat from the ground. The electrical power demand of the circulation pump must then be considered as auxiliary electricity for the specific primary energy demand.

In former versions of the PHPP and PHLuft instead of the efficiency a rate of heat provision was used, which in winter directly determined the reduction of ventilation heat losses. This value not only depends on the characteristics of the SHX, but also on the indoor, outdoor and ground temperature. If there is only the rate of heat provision on hand, you can determine the corresponding efficiency in the **Ventilation** worksheet by trial and error.

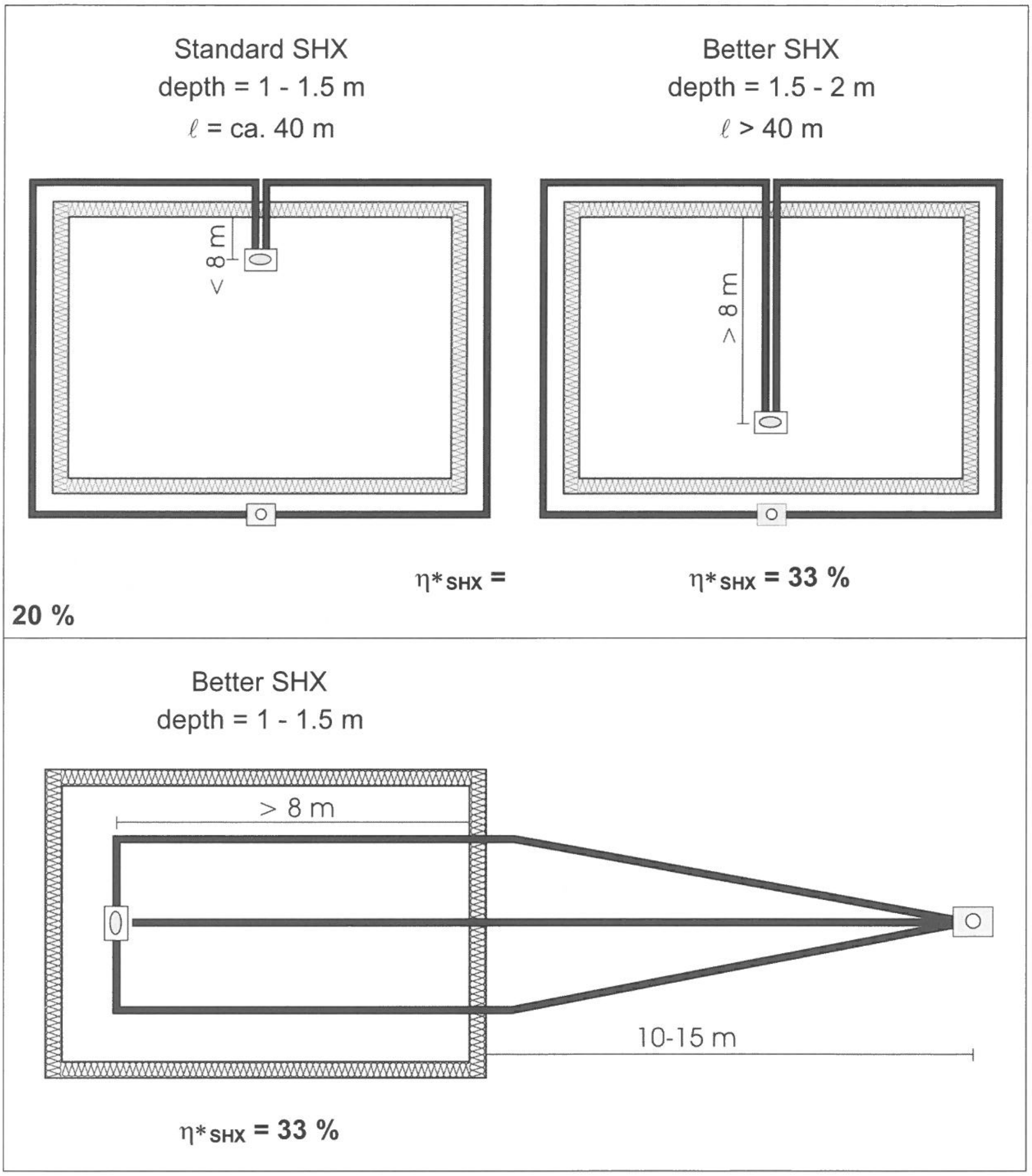


Figure 19: Recommended installations for air subsoil heat exchangers with corresponding efficiency η^*_{SHX}

15 "Annual Heat Demand" Worksheet: Calculating the Annual Heat Demand According to the PHPP method

The PHPP method generally follows the European Standard EN 13790 [DIN EN ISO 13790]. On this worksheet, all values are automatically retrieved from other worksheets. Usually no data entry is required.

15.1 Heat Demand Balance

The formula used to determine the energy balance is shown in the diagram below.

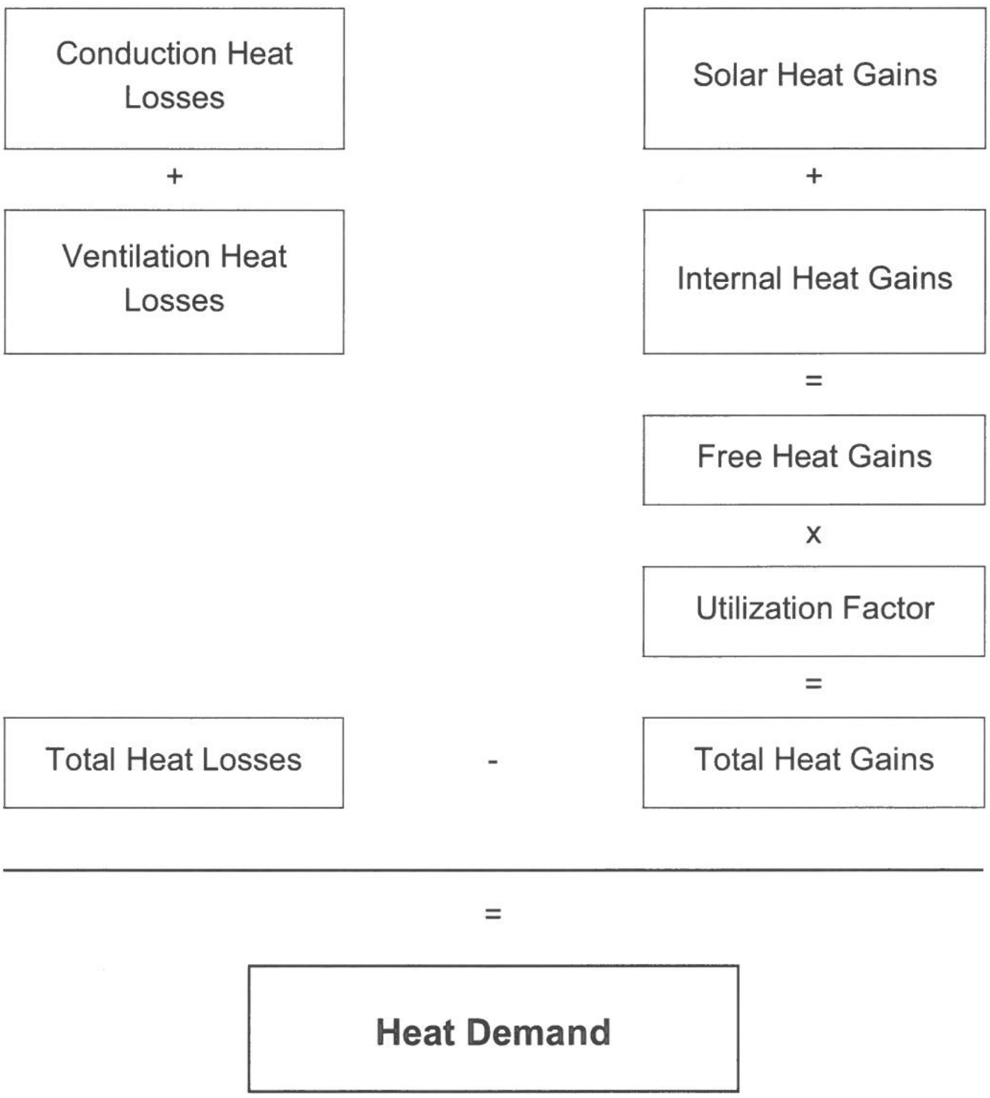


Figure 20: Energy balance diagram

15.2 Heat Losses

15.2.1 Conduction Heat Losses Q_T

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	184.3	*	0.138	*	1.00	*	84.0	=	2129	
2.	Exterior Wall - Ground	B		*		*	0.59	*		=		
3.	Roof/Ceiling - Ambient	A	83.4	*	0.108	*	1.00	*	84.0	=	753	
4.	Floor Slab	B	80.9	*	0.131	*	0.59	*	84.0	=	520	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	43.5	*	0.777	*	1.00	*	84.0	=	2838	
9.	Exterior Door	A		*		*	1.00	*		=		
10.	Exterior TB (length/m)	A	116.9	*	-0.030	*	1.00	*	84.0	=	-292	
11.	Perimeter TB (length/m)	P		*		*	0.59	*		=		
12.	Ground TB (length/m)	B	11.4	*	0.061	*	0.59	*	84.0	=	34	
		Total of All Building Envelope Areas	392.1									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	5982	38.3

Annual heat losses are calculated for every building element comprising the thermal envelope using the formula

$$Q_T = A \cdot U \cdot f_T \cdot G_t$$

A: building element area (automatically transferred from the linked **Areas** worksheet)

U: building element U-value (automatically transferred from the linked **Areas** worksheet)

f_T: reduction factor for reduced temperature differences

G_t: temperature difference time integral (heating degree hours)

15.2.1.1 Temperature Zones

The temperature zones selected in the **Areas** worksheet are automatically transferred to the **Annual Heat Demand** worksheet.

15.2.1.2 Areas

For calculating the building element areas, the exterior dimensions of the insulated building envelope are used. The dimensions of the rough openings are used as the inputs for the windows (see the **Windows** worksheet). These values are generated in the **Areas** worksheet.

15.2.1.3 Heating Degree Hours

User-defined climate data can be entered on the **Climate Data** worksheet. The interior temperature, which is specified on the **Verification** worksheet, should only be altered in justified cases

15.2.1.4 Temperature Weighting Factors

The temperature weighting factors calculated in the **Areas** worksheet are automatically transferred to the **Annual Heat Demand** worksheet.

15.2.1.5 U-Values

The average U-values of the building element groups calculated on the **Areas** worksheet are automatically transferred to the **Annual Heat Demand** worksheet.

15.2.1.6 Window Conduction Losses

Window quality plays an important role in Passive House buildings. With design temperatures of –10 °C or lower, interior comfort in front of a window without a supplementary heat source is only possible if the U-value of the window is below 0.8 $W/(m^2K)$ and the window height does not exceed 3 m [Feist 1993], [Schnieders 2001]. If windows are south facing and are only minimally shaded, they can contribute more solar heat to the rooms by radiation than they lose by conduction, even in the middle of the Central European winter.

The window U-value depends not only on the quality of the glazing, but also on the quality of the window frame, the quality of the spacer, the quality of the installation, and the glass to frame ratio. The **Windows** worksheet contains an accurate formula that takes these factors into account. On this worksheet, the user defines the orientation, area, and U-value for each window. The total passive solar gains are calculated from these parameters, and the results are automatically transferred to the **Annual Heat Demand** worksheet.

Windows installed in masonry or concrete walls with exterior insulation should be placed in the plane of the insulation, not in the plane of the masonry.

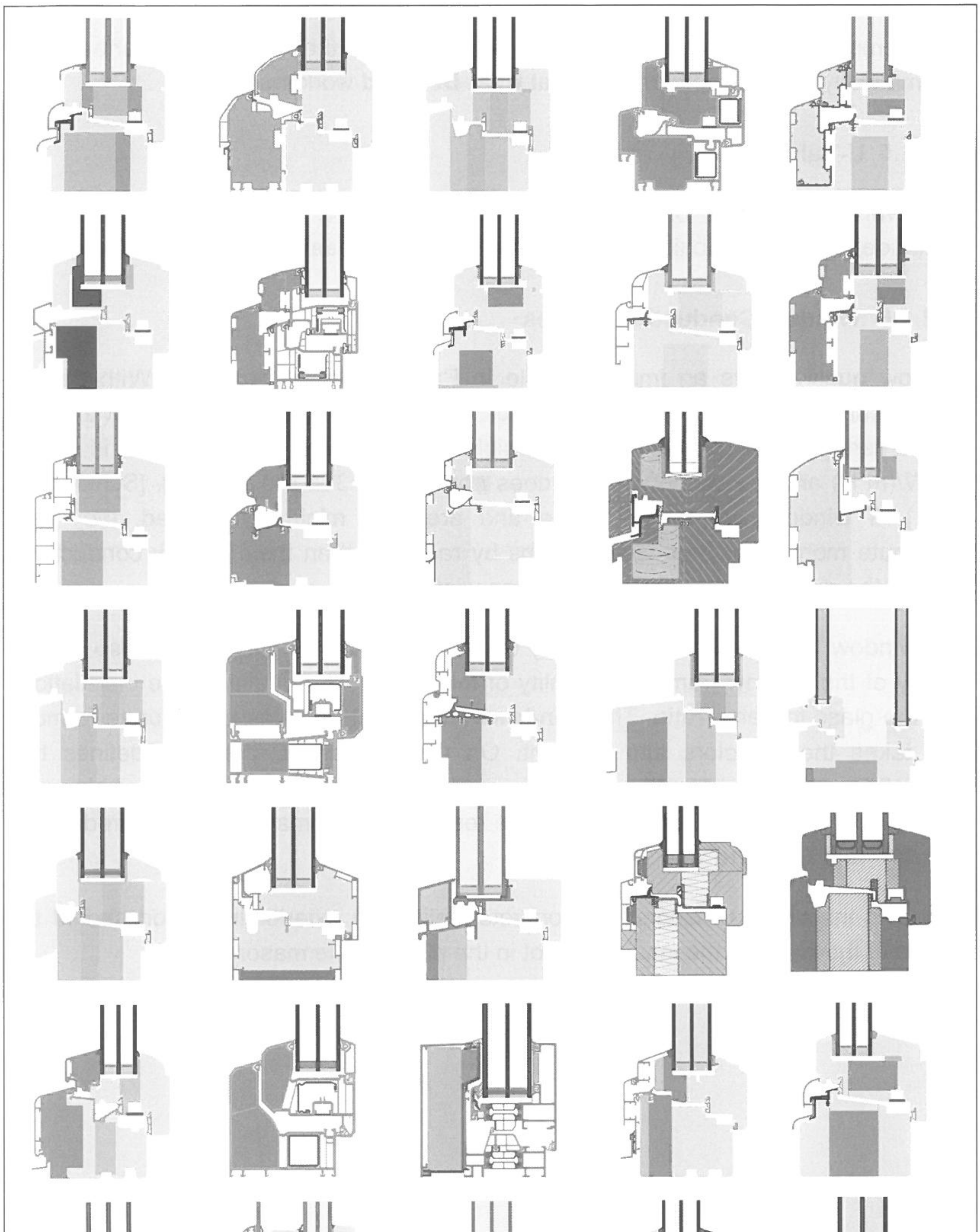


Figure 21: Some of the windows certified by the PHI as suitable for Passive Houses (all certified windows can be found at www.passiv.de).

15.2.1.7 Thermal Bridges

The exterior dimensions of the building envelope are used in the PHPP (see the **Areas** worksheet), so the losses resulting from **geometrical thermal bridges** are generally already accounted for in the calculated conduction losses. The heat loss coefficients for overlapping geometries are normally negative when using exterior dimensions. Therefore, the heat losses are usually overestimated using this simplified calculation method [AkkP 16].

Thermal bridges in construction should be avoided not only because of the associated energy losses, but also to ensure the level of comfort within the building and avoid damage to building components through moisture from condensation around thermal bridges.

Generally the design goal should be to detail the connections between building envelope assemblies, e.g. roof and wall, in such a way that an uninterrupted layer of insulation is created. This layer should have an overall thickness that corresponds to the thickness entered on the **U-Values** worksheet for the various building elements. Furthermore, any supports for reinforced concrete slabs, window headers, or concrete columns in exterior walls have to be designed so that they are surrounded by a full uninterrupted thickness of the insulation layer. The resulting thermal bridge losses can then be ignored. If all building elements are designed and built in accordance with these principles, then “thermal bridge-free” construction is achieved.

This is true, in particular, of details that have been certified by the Passive House Institute (PHI) as “Suitable Connections for Passive Houses”, for which it has been verified that the thermal bridge coefficient is

$$\Psi \leq \mathbf{0.01\ W/(mK)}$$

and that the connection is free of condensation.

If it is not possible to avoid thermal bridges completely, the thermal bridge effects should be reduced as much as possible through thermal separation. For some typical thermal bridges the following solutions can be effective and affordable:

- Window connections to walls with exterior insulation:
  Set the window flush with the exterior side of the masonry wall, i.e. into the insulating layer, and lap the exterior insulation approx. 4 cm over the window frame.
- Connection of the basement ceiling slab to the exterior wall:
  Place a base course of aerated concrete blocks or specially designed insulation blocks to form a thermal break (e.g. cellular glass insulation or Purenit). The

thermal break must connect with the layers of insulation of the exterior wall and the basement ceiling slab, clearly separating the warm side from the cold side.

- Balconies:
  Instead of a cantilevered balcony slab, a thermally broken cantilever support or a completely separate, self-supporting structure should be used.

The topic of thermal bridges is covered in detail in the publication "*Protokollband 16: Wärmebrückenfreies Konstruieren*" (Thermal Bridge-Free construction), available in German from the PHI [AkkP 16]. The publication [AkkP 35] contains further information on thermal bridges, particularly solutions for building components such as plinths, balconies, or curtain walls, for which thermal bridge-free solutions can be difficult to achieve.

The additional conduction losses of the thermal bridges are automatically calculated by the PHPP using the following formula:

$$Q_T = \ell \cdot \Psi \cdot f_T \cdot G_t$$

ℓ: length of the thermal bridge

Ψ: thermal bridge heat loss coefficient (relative to the exterior dimensions of the building elements)

f_T: reduction factor (see 15.2.1.4)

G_t: time integral of the temperature difference (heating degree hours)

15.2.2 Ventilation Heat Losses

The ventilation heat losses are calculated using the following formula:

$$Q_V = n_V \cdot V_V \cdot c \cdot G_t$$

n_V: energetically effective air exchange rate

V_V: reference volume of the ventilation system (= TFA x average room height)

c: specific heat capacity of air: 0.33 Wh/(m³K)

G_t: heating degree hours referenced to ambient air

					A_{TFA} m²		Clear Room Height m		m³	
Ventilation System:	Effective Air Volume, V_V				156.0	*	2.50	=	390.0	
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff} 82%									
Efficiency of Subsoil Heat Exchanger	η_{SHX} 35%		$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h	
Energetically Effective Air Exchange n_v			0.300	*(1 -	0.88	) +	0.019	=	0.054	
	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	390	*	0.054	*	0.33	*	84.0	=	585	3.7

The air volume V_V, is the energy reference area (Treated Floor Area, A_{TFA}, see Chapter 7.8) multiplied by the room height. A standard residential room height of 2.5 m is used for calculation purposes. For greater room heights in residential buildings it is recommended to not enter a larger value, since this would tend to result in an excessive exchanged air volume and an indoor humidity level during the winter that may be too low.

Advice

If no air volume has been entered for the pressurization test on the **Ventilation** worksheet, the PHPP will use a standard pressurization value of 0.6 h^{-1} relative to the effective air volume. When calculated relative to the generally larger pressurization test reference volume, a significantly better pressurization test value may be assumed than is actually the case. You will want to enter the actual reference volume for the pressurization test as early as possible on the **Ventilation** worksheet.

The energetically effective air exchange rate using heat recovery is calculated using the following formula:

$$n_V = n_{V,System} \cdot (1 - \Phi_{HR}) + n_{V,Res}$$

$n_{V,\,System}$: The average air exchange rate achieved through the ventilation system. The standard value for residences is 0.4 h^{-1}, however, a more accurate value can be obtained on the **Ventilation** worksheet. If the average exchange rate is not calculated in detail, the PHPP will use the standard value for the air exchange rate. The standard air exchange rates for some building types are given in Table 9. However, it is recommended to perform a more accurate calculation on the **Ventilation** worksheet.

Table 9: Typical building air exchange rates.

	Residential	Assisted Living	Administration [1)]	School [2)]	Other
Natural Ventilation	0.6	0.6	0.75[3)]	0.41[4)]	More accurate calculation required
Mechanical Ventilation	0.4	0.5	0.35	0.60	More accurate calculation required

1) Occupied 69 % of the heating period

2) Occupied 26 % of the heating period

3) When occupied 1.0 h^{-1}, all other times 0.2 h^{-1}

4) When occupied 1.0 h^{-1}, all other times 0.2 h^{-1}

$n_{Infiltration}$: Infiltration air exchange due to leakage through the building envelope: Standard Value = 0.042 h-1. This value corresponds to a 50 Pa pressurization test result (blower door test) of 0.6 h-1, the highest value permitted for Passive House buildings. The precise value for the infiltration air exchange rate is determined after the pressurization test result as well as the net air volume for the pressurization test have been entered on the **Ventilation** worksheet.

Φ_{HR}: The total heat recovery efficiency of the heat recovery system is determined using:

$$\Phi_{HR} = 1 - (1 - \eta_{eff}) \cdot (1 - \eta_{SHX})$$

η_{eff}: The heat recovery efficiency of the heat recovery system takes in to account heat losses from the ducts between the heat recovery unit and the exterior building envelope. The calculations take place on the **Ventilation** worksheet.
If no definite specifications are available for the counter-flow heat exchanger, a η_{HR} value (on the **Ventilation** worksheet) of 75 % can be used. Cross flow heat exchangers have a lower efficiency. Without sufficiently accurate measurement results, the value used must not exceed 50 %.

η_{SHX}: The efficiency of the subsoil heat exchanger (or buried ducts for fresh air intake) is taken from the **Ventilation** worksheet.

15.2.3 Total Heat Losses

$$Q_L = Q_T + Q_V$$

15.3 Heat Gains

15.3.1 Internal Heat Gains

			Length Heat. Period		Spec. Power q_I		A_{TFA}			
	kh/d		d/a		W/m²		m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	225	*	2.10	*	156.0	=	1769	11.3
									kWh/a	kWh/(m²a)
			Free Heat Q_F				Q_S + Q_I	=	4706	30.2

The internal heat gains, Q_i, are the sum of the heat generated by people and household appliances during the heating period. The energy needed for heating cold water and water evaporation must be deducted from the total sum of internal heat gains. These effects act as a negative internal heat gain. [Feist 1994]

The internal heat gains are estimated for standard living conditions and entered as a standard value:

> 2.1 W/m² treated floor area for single family homes, multi family homes, and terraced houses
> 4.1 W/m² treated floor area for assisted living facilities
> 3.5 W/m² treated floor area for office and administration buildings
> 2.8 W/m² treated floor area for schools

The selection of the building type can be made on the **Verification** worksheet. A more detailed calculation is required for other building types.

Individual values can be entered on the **IHG** worksheet (see Chapter 34). This worksheet provides an accurate determination of the internal heat gains for residential buildings. The worksheet becomes a component of the certification report if the calculated result is used in the energy balance.

15.3.2 Solar Radiation

The solar heat gain is calculated using the formula:

$$\mathbf{Q_S = r \cdot g \cdot A_W \cdot G}$$

r: The reduction factor takes into account the frame to window area ratio, shading, dirt on the windows, and the angle of inclination of radiation through the window. The façades of Passive Houses should mostly remain unshaded and have a low frame to window area ratio. These factors must be considered during the design phase! The reduction factor is automatically calculated using the inputs for the window geometry on the **Windows** worksheet. The reduction factor is then averaged for all of the windows of the respective orientation and transferred to the **Annual Heat Demand** worksheet. For calculation of the shading factors, see the **Windows** and **Shading** worksheets.

g: Total solar energy transmission coefficient for the glazing at a normal to the irradiated surface. The g value is taken from the **Windows** worksheet.

A_W: Window area (rough opening)

G: Total radiation during the heating period, averaged over all of the project's windows. This value is automatically calculated on the **Windows** worksheet once the window geometries, angular deviation from true north, and inclination angle have been entered, and is then carried over to the **Annual Heat Demand** worksheet. The total radiation is also dependent on the climate region. The appropriate region is to be selected on the **Climate Data** worksheet. For consideration of the shading factors, see the **Windows** and **Shading** worksheets.

		QT kWh/a		QV kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	5982	+	585	)	* 1.0	=	6567	42.1

Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1. North	0.46	*	0.50	*	11.04	*	140	=	356	
2. East	0.40	*	0.00	*	0.00	*	220	=	0	
3. South	0.44	*	0.50	*	30.42	*	370	=	2489	
4. West	0.40	*	0.50	*	2.00	*	230	=	92	
5. Horizontal	0.40	*	0.00	*	0.00	*	360	=	0	
Available Solar Heat Gains Q_S								Total	2937	18.8

To obtain the global radiation, the solar radiation over the heating period for each of the orientations is used.

15.4 Free Heat (Heat Gains)

Free heat is the sum of the interior heat sources and the solar gains during the heating period.

$$Q_F = Q_I + Q_S \qquad \text{(internal sources + solar gains)}$$

15.5 Free Heat Utilisation Factor

The free heat utilization factor is defined as the fraction of free heat that can be used for space heating. Surplus heat, e.g. excess solar gains, is not or only partially usable. The free heat utilization factor is calculated using the following formula:

$$\eta_G = \frac{1 - (Q_F/Q_L)^5}{1 - (Q_F/Q_L)^6}$$

15.6 Useful Heat Gains

$$Q_G = Q_F \cdot \eta_G \text{ (Free Heat x Free Heat Utilization Factor)}$$

15.7 Heat Demand

15.7.1 Annual Heat Demand

$$Q_H = Q_L - Q_G \qquad \text{(Losses - Gains)}$$

15.7.2 Specific Annual Heat Demand q_H

$$q_H = \frac{Q_H}{A_{TFA}}$$

Q_H: annual heat demand

A_{TFA}: energy reference area (TFA, or usable occupied area; see Chapter 7.8)

15.8 Requirement

The upper limit for the specific annual heat demand for Passive House buildings is:

$$q_H \leq 15 \text{ kWh/(m}^2\text{a)}$$

This value applies to the total building enclosed within the thermal envelope.

For terraced houses and blocks of flats, this means that the average value for all the dwelling units within the thermal envelope can be determined. However, this does not guarantee that each unit or room will be able to be heated using the supply air alone. Please use the **Heating Load** worksheet to size the heating system.

Detached house in Lüdighausen, Germany
Photo: Westdeutsche LBS

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	Standard	Interior Temperature:	20.0 °C
Building:	End-of-Terrace Passive House Kranichstein	Building Type/Use:	Terraced House/Dwellings
Location:	Darmstadt Kranichstein	Treated Floor Area A_{TFA}:	156.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	184.3	*	0.138	*	1.00	*	84.0	=	2129	
2.	Exterior Wall - Ground	B		*		*	0.59	*		=		
3.	Roof/Ceiling - Ambient	A	83.4	*	0.108	*	1.00	*	84.0	=	753	
4.	Floor Slab	B	80.9	*	0.131	*	0.59	*	84.0	=	520	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	43.5	*	0.777	*	1.00	*	84.0	=	2838	
9.	Exterior Door	A		*		*	1.00	*		=		
10.	Exterior TB (length/m)	A	116.9	*	-0.030	*	1.00	*	84.0	=	-292	
11.	Perimeter TB (length/m)	P		*		*	0.59	*		=		
12.	Ground TB (length/m)	B	11.4	*	0.061	*	0.59	*	84.0	=	34	
	Total of All Building Envelope Areas		392.1									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	5982	38.3

			A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V		156.0	*	2.50	=	390.0
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	82%					
Efficiency of Subsoil Heat Exchanger	η_{SHX}	35%					

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_V	0.300	*(1 -	0.88	) +	0.019	=	0.054

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	390	*	0.054	*	0.33	*	84.0	=	585	3.7

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	5982	+	585	) *	1.0	=	6567	42.1

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.46	*	0.50	*	11.04	*	140	=	356	
2.	East	0.40	*	0.00	*	0.00	*	220	=	0	
3.	South	0.44	*	0.50	*	30.42	*	370	=	2489	
4.	West	0.40	*	0.50	*	2.00	*	230	=	92	
5.	Horizontal	0.40	*	0.00	*	0.00	*	360	=	0	
	Available Solar Heat Gains Q_S								Total	2937	18.8

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	225	*	2.10	*	156.0	=	1769	11.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	4706	30.2
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.72	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	94%	
Heat Gains Q_G	$\eta_G * Q_F$	=	4415	28.3
Annual Heat Demand Q_H	$Q_L - Q_G$	=	2152	**14**

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	**Yes**

16 "Monthly Method" Worksheet: Calculating the Annual Heat Demand According to EN 13790 / Monthly Method

In the **Annual Heat Demand** worksheet the energy balance is calculated using a heating period method. The monthly method of the EN 13790, however, performs an energy balance for every month of the year. All the building data are adopted from the **Annual Heat Demand** worksheet.

The thermal storage capacity is required in addition to the building information. This value is adopted from the **Summer** worksheet. The influence of the thermal storage capacity is very low when applying the monthly method to Passive Houses. It is given as a default value of 204 Wh/K per m^2 of the occupied area in the **Summer** worksheet.

No data entry is required in this worksheet.

For the monthly method, a set of standard climate data is used which corresponds to the annual data from the **Annual Heat Demand** worksheet. There is also an option for selecting regional climate data from the **Climate Data** worksheet, from which equivalent annual data are generated for the **Annual Heat Demand** worksheet. There are monthly calculation procedures for an exact determination of the effects of orientation and shading conditions which use the same input as the annual method.

The results of the annual heat demand calculations of both methods are comparable and, in most cases, very similar, because both methods are based on the same climate data. Exceptions with dissimilar results have been observed in buildings with large glazing areas and very low heat demands considerably below the level required for Passive Houses. In such cases the monthly method should be used (see the **Verification** worksheet).

Note: Losses, gains, and the utilization factor cannot be compared between methods because they relate to different time intervals. Only the result (i.e. the annual heat demand) is relevant.

Additional monthly heat demands are calculated and graphically illustrated in the monthly method. Note that the monthly results only partially match dynamic building simulations, i.e. the values at the beginning of the heating period tend to be higher and at the end to be lower than the values in dynamic simulations. The method in accordance with EN 13790 is a semi-dynamic method. It does not fully consider thermal storage effects.

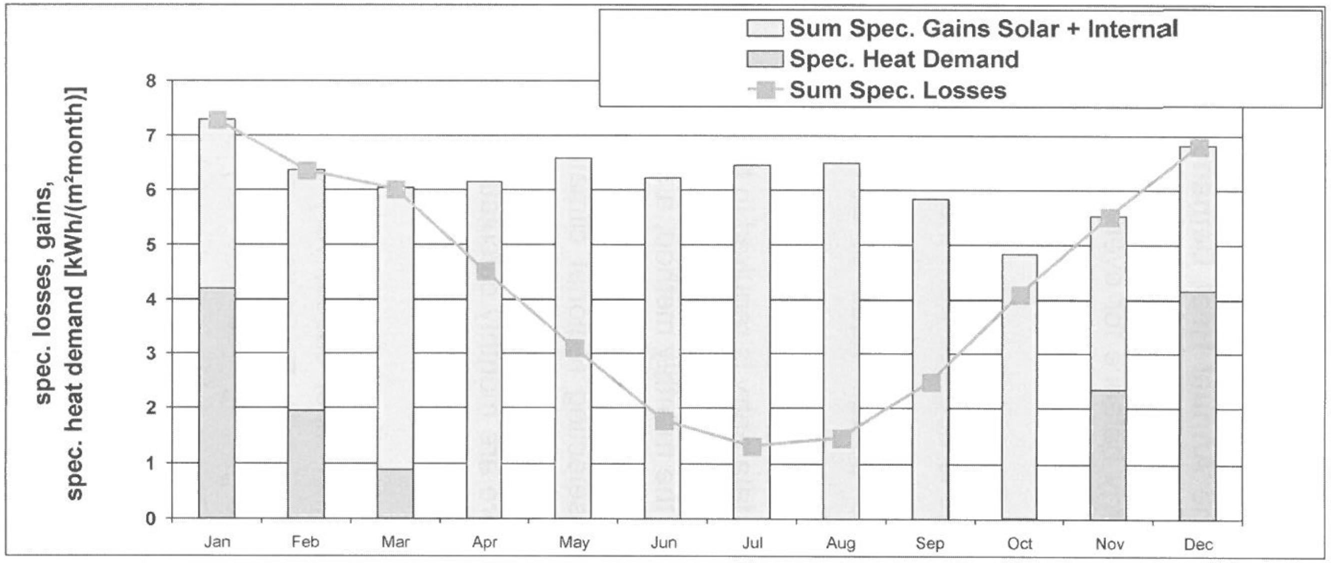
PASSIVE HOUSE PLANNING

SPECIFIC ANNUAL HEAT DEMAND MONTHLY METHOD

Climate: Standard Germany
Building: End-of-Terrace Passive House Kranichstein
Location: Darmstadt Kranichstein

Interior Temperature: 20 °C
Building Type/Use: Terraced House/Dwellings
Treated Floor Area A_{TFA}: 156 m²

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating Degree Hours - Exterior	14.9	12.8	11.9	8.6	5.5	2.9	2.0	2.4	4.6	8.1	11.2	13.9	99	kKh
Heating Degree Hours - Ground	7.4	7.0	7.6	6.9	6.3	4.7	4.2	3.9	4.5	5.2	5.8	6.8	70	kKh
Losses - Exterior	1004	867	802	583	373	194	133	162	308	546	760	942	6674	kWh
Losses - Ground	132	124	135	122	112	83	75	69	80	92	103	121	1249	kWh
Sum Spec. Losses	7.3	6.4	6.0	4.5	3.1	1.8	1.3	1.5	2.5	4.1	5.5	6.8	50.8	kWh/m²
Solar Gains - North	25	38	66	94	127	140	140	112	76	46	25	18	908	kWh
Solar Gains - East	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solar Gains - South	195	397	444	558	572	511	538	578	538	424	215	141	5112	kWh
Solar Gains - West	6	11	18	26	33	32	33	29	22	14	6	4	235	kWh
Solar Gains - Horiz.	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solar Gains - Opaque	11	22	31	43	52	50	52	47	38	25	13	8	392	kWh
Internal Heat Gains	244	220	244	236	244	236	244	244	236	244	236	244	2870	kWh
Sum Spec. Gains Solar + Internal	3.1	4.4	5.1	6.1	6.6	6.2	6.5	6.5	5.8	4.8	3.2	2.7	61.0	kWh/m²
Utilisation Factor	100%	100%	100%	74%	47%	29%	21%	23%	43%	85%	100%	100%	61%	
Annual Heat Demand	655	303	138	0	0	0	0	0	0	2	367	647	2112	kWh
Spec. Heat Demand	**4.2**	**1.9**	**0.9**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**2.4**	**4.1**	**13.5**	kWh/m²



17 "Heating Load" Worksheet: Determining the Space Heating Load

This worksheet offers a tool for planning the maximum building heating load. Differing from e.g. DIN EN 12831, this worksheet determines not only heat losses but also heat gains and the thermal inertia in an adequate manner. The method is suitable for Passive Houses only.

Based on the results of dynamic building simulations, it became obvious that the maximum heating load may occur in two situations depending upon the building [Bisanz 1999]:

- on a cold but sunny winter day with a cloudless sky (high pressure weather situation), or
- on a moderately cold but overcast day with minimal solar radiation.

Therefore a simple energy balance between heat-loss and heat-gain flows for two different weather situations is carried out in the worksheet:

Cold, Clear Day		**Moderate, Overcast Day**	
Conduction Heat Losses + Ventilation Heat Losses	Solar Heat Gains + Internal Heat Sources (People & Appliances)	Conduction Heat Losses + Ventilation Heat Losses	Solar Heat Gains + Internal Heat Sources (People & Appliances)
Heat-Loss Flows -	Heat-Gain Flows	Heat-Loss Flows -	Heat-Gain Flows
= Heating Load Cold Day		**= Heating Load Overcast Day**	
Heating Load = max (Heating Load Cold Day; Heating Load Overcast Day)			

For physical reasons very low temperatures always occur when the sky is clear. When the sky is overcast, the earth's surface can only radiate a lower amount of heat to the high, cold layers of the atmosphere. This heat loss can not be compensated for by the moderate solar radiation in winter. Climates do exist, in which the splitting into two heating load days is not necessary. This applies for instance to locations which are affected by the polar night or to valleys in which cold air "lakes" with a layer of fog lying above develop.

17.1 Climate Data for Heating Load Calculations

The climate data required for the heating load calculation were generated by using dynamic simulations. A complete set of climate data for the PHPP also contains heating load data. Because the determination of climate data is quite complex, no heating load data are available for some climates.

The climate data for the heating load calculation are selected in the **Climate Data** worksheet (see the chapter about Climate Data) together with the climate data set. Therefore an individual entry for the **Heating Load** worksheet is not necessary.

17.2 Building Data

All required information about the thermal envelope of the building and the ventilation system is automatically supplied by the **Annual Heat Demand** worksheet.

17.3 Walls and Ceilings between Adjacent Residential Units

For the calculation of the annual heat demand, it is assumed that there is no heat flow between residential units of terraced houses and multi-unit housing contained within a single thermal envelope. The assumption of equal room temperatures is justifiable because a loss in one residential unit is always a gain in the neighbouring unit. However, if heating loads are to be calculated, the heat flows between units must be considered. For example, a dwelling unit must continue to be sufficiently heated when a neighbour has lowered or shut off his heating system while on vacation.

This effect can be considered for sizing the heating load by adding the neighbouring building element areas to the calculation in the **Heating Load** worksheet. The assumed temperature difference of 3 °C is relatively low. Previous experiences in Passive Houses show that this temperature difference is sufficient because the high thermal inertia causes temperatures to decrease very slowly. For Passive Houses adjacent to poorly insulated existent buildings, increasing the temperature difference to the neighbouring housing unit to 5 °C can make sense (for this, please cancel the write protection of the worksheet and enter the higher value in the adequate cell).

	Building Element	Temperature Zone	m²		W/(m²K)		Always 1 (except "X")		K		K		W		W
1.	Exterior Wall - Ambient	A	184.3	*	0.138	*	1.00	*	30.6	or	21.2	=	774	or	538
2.	Exterior Wall - Ground	B		*		*	1.00	*	10.4	or	10.4	=		or	
3.	Roof/Ceiling - Ambient	A	83.4	*	0.108	*	1.00	*	30.6	or	21.2	=	274	or	191
4.	Floor Slab	B	80.9	*	0.131	*	1.00	*	10.4	or	10.4	=	110	or	110
5.		A		*		*	1.00	*	30.6	or	21.2	=		or	
6.		A		*		*	1.00	*	30.6	or	21.2	=		or	
7.		X		*		*	0.75	*	30.6	or	21.2	=		or	
8.	Windows	A	43.5	*	0.777	*	1.00	*	30.6	or	21.2	=	1033	or	718
9.	Exterior Door	A		*		*	1.00	*	30.6	or	21.2	=		or	
10.	Exterior TB (length/m)	A	116.9	*	-0.030	*	1.00	*	30.6	or	21.2	=	-106	or	-74
11.	Perimeter TB (length/m)	P		*		*	1.00	*	10.4	or	10.4	=		or	
12.	Ground TB (length/m)	B	11.4	*	0.061	*	1.00	*	10.4	or	10.4	=	7	or	7
13.	House/Apartment Party Wall	I	84.8	*	0.375	*	1.00	*	3.0	or	3.0	=	96	or	96
	Transmission Heat Losses P_T										Total	=	2188	or	1586

17.4 Internal Heat Gains

The value for the internal heat sources is not simply carried over from the **Annual Heat Demand** worksheet because it calculates the average for the entire heating period. It must be possible to heat the house in unusual situations as well (e.g., only one person present and therefore missing internal heat gains). Therefore, generally a value of 1.6 W/m² for internal heat sources is used in the heating load calculation.

17.5 Heat Losses

$$P_L = \Sigma \left(A_i \cdot U_i \cdot f_T \cdot \begin{matrix} \Delta\vartheta_1 \\ \text{or} \\ \Delta\vartheta_2 \end{matrix} \right) + V_V \cdot n_V \cdot c_{Air} \cdot \begin{matrix} \Delta\vartheta_1 \\ \text{or} \\ \Delta\vartheta_2 \end{matrix}$$

A_i: building element area

U_i: building element U-value

f_T: temperature factor. Usually 1.0. For temperature zone "X", the temperature factor is the same as in the **Annual Heat Demand** worksheet.

$\Delta\vartheta_1$: temperature difference of the building element for weather condition 1

$\Delta\vartheta_2$: temperature difference of the building element for weather condition 2

V_V: air volume

n_V: energetically effective air exchange for heating load design conditions; for infiltration 2.5 times the value of the average of the heating period is used.

c_{Air}: heat capacity of air

17.6 Heat Gains

$$P_G = \Sigma \left(A_{W,i} \cdot g_i \cdot r_i \cdot \begin{matrix} G_1 \\ \text{or} \\ G_2 \end{matrix} \right) + p_i \cdot A_{TFA}$$

$A_{W,i}$: window area

g_i: solar heat gain coefficient

r_i: reduction factor (depending on shading)

G_1, G_2: solar radiation dependent on orientation for weather conditions 1 & 2

p_i: internal specific heat gains

A_{TFA}: treated floor area

17.7 Maximum Heating Load

The maximum heating load is calculated from

$$P_H = \max (P_L - P_G)$$

P_L: heat losses

P_G: heat gains

Annual Heating Load P_H		=		1559	W
Specific Annual Heating Load P_H / A_{TFA}		=		10.0	W/m²
Input Max. Supply Air Temperature	52 °C		°C		°C
Max. Supply Air Temperature $\vartheta_{zu,Max}$	52 °C	Supply Air Temperature Without Supplementary Heating $\vartheta_{Supply,Min}$	17.9		18.1
For Comparison: Heating Load that is Transportable in the Supply Air. $P_{Supply\,Air,Max}$	=	1315 W	specific:	8.4	W/m²

Advice

> The heating system must be able to generate and distribute *at least* the heating load calculated here. The heating load does not only occur in exceptional cases but frequently even during several weeks in the midst of winter.

17.8 Maximum Heating Load Transportable through the Supply Air

The maximum heating power $P_{supply,max}$ which can be transported through the ventilation system is determined using the following formula:

$$P_{supply,max} = (\vartheta_{supply,max} - \vartheta_{supply,min}) \cdot c_{Air} \cdot V_{V,system}$$

$\vartheta_{supply,max}$: maximum supply air temperature, 52 °C

$\vartheta_{supply,min}$: supply air temperature without supplementary heat sources calculated from ambient air temperatures and from the heat recovery efficiency of the ventilation system using the following formula:

$$\vartheta_{supply,min} = \vartheta_{ambient,min} + \Phi_{HR} \cdot (\vartheta_{interior} - \vartheta_{ambient,min})$$

c_{Air}: heat capacity of air

$V_{V,system}$: the volume of air flowing through the ventilation system

The condition for using fresh air as heat source is

$$P_H \leq P_{supply,max}$$

If the heating load value P_H exceeds the allowed value $P_{supply,max}$, an additional heating system is necessary.

The accuracy of the heating load calculation was proven using dynamic thermal building simulations. It has been proven in the past to be adequate. For determining the heating load data a set of dynamic simulation calculations based on hourly climate data is necessary to this date.

The maximum temperature of the supply air has been restricted to 52 °C. However, not all heat generators meet this value. Then correspondingly less heat can be transported by the supply air. This is the case for some heat pump compact units. The actual maximum temperature of the supply air, can explicitly be entered by the user.

Advice to the mechanical system consultant: The nominal heating power of the reheater given by the manufacturers, frequently refers to other temperature combinations and / or air flow rates than in the specific project. Not taking this fact into account can result in an undersizing of the reheater, which can put the correct functioning of the building into question.

The worksheet is helpful for sizing the heat generator as well as for determining heating loads for separate groups of rooms.

The calculations do not contain any effects of dynamic heating loads (warming up, cycles of nightly temperature reductions and daily reheating). It is recommended not to reduce the room temperature in Passive Houses during the critical heating period. This does not cause a significant cost increase, and it has the advantage that one always returns to a warm home. It is recommended to use a portable heat source (e.g. liquid gas heaters) for reheating the home after a long cool down period, or when initially heating the home (e.g. moving into a new Passive House in winter).

In specific types of non-residential buildings, e.g. in schools, it can be appropriate to lower the room temperature in off-use periods. Using this operational mode the necessary low-temperature operating mode and the preheating powers have to be taken into account. See [AkkP 33] for more information on Passive House schools (in German).

Passive House Planning

SPECIFIC SPACE HEATING LOAD

Building:	End-of-Terrace Passive House Kranichstein	Building Type/Use:	Terraced House/Dwellings
Location:	Darmstadt Kranichstein	Treated Floor Area A_{TFA}:	156.0 m² — Interior Temperature: 20 °C
		Climate (HL):	Standard Germany

	Design Temperature		Radiation: North	East	South	West	Horizontal	
Weather Condition 1:	-10.6	°C	10	30	90	35	40	W/m²
Weather Condition 2:	-1.2	°C	5	5	10	5	10	W/m²
Ground Design Temp.	9.6	°C						

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Factor Always 1 (except "X")		TempDiff 1 K		TempDiff 2 K		P_T 1 W		P_T 2 W
1.	Exterior Wall - Ambient	A	184.3	*	0.138	*	1.00	*	30.6	or	21.2	=	774	or	538
2.	Exterior Wall - Ground	B		*		*	1.00	*	10.4	or	10.4	=		or	
3.	Roof/Ceiling - Ambient	A	83.4	*	0.108	*	1.00	*	30.6	or	21.2	=	274	or	191
4.	Floor Slab	B	80.9	*	0.131	*	1.00	*	10.4	or	10.4	=	110	or	110
5.		A		*		*	1.00	*	30.6	or	21.2	=		or	
6.		A		*		*	1.00	*	30.6	or	21.2	=		or	
7.		X		*		*	0.75	*	30.6	or	21.2	=		or	
8.	Windows	A	43.5	*	0.777	*	1.00	*	30.6	or	21.2	=	1033	or	718
9.	Exterior Door	A		*		*	1.00	*	30.6	or	21.2	=		or	
10.	Exterior TB (length/m)	A	116.9	*	-0.030	*	1.00	*	30.6	or	21.2	=	-106	or	-74
11.	Perimeter TB (length/m)	P		*		*	1.00	*	10.4	or	10.4	=		or	
12.	Ground TB (length/m)	B	11.4	*	0.061	*	1.00	*	10.4	or	10.4	=	7	or	7
13.	House/Apartment Party Wall	I	84.8	*	0.375	*	1.00	*	3.0	or	3.0	=	96	or	96

Transmission Heat Losses P_T

Total = 2188 or 1586

Ventilation System:

Effective Air Volume, V_V: A_{TFA} 156.0 m² * Clear Room Height 2.50 m = 390 m³

Efficiency of Heat Recovery of the Heat Exchanger η_{HR}: 82%

Heat Recovery Efficiency SHX: 93%

Efficiency SHX: η_{SHX} 1: 63% or η_{SHX} 2: 49%

Energetically Effective Air Exchange n_V: $n_{V,Res}$ (Heat Load) 0.047 1/h + $n_{V,system}$ 0.300 1/h *(1- Φ_{HR} 0.93 or Φ_{HR} 0.91) = 0.068 1/h or 0.075 1/h

Ventilation Heating Load P_V

V_L m³		n_L 1/h		n_L 1/h		c_{Air} Wh/(m³K)		TempDiff 1 K		TempDiff 2 K		P_V 1 W		P_V 2 W
390.0	*	0.068	or	0.075	*	0.33	*	30.6	or	21.2	=	**266**	or	**204**

Total Heating Load P_L

$P_T + P_V$ = P_L 1: **2453** W or P_L 2: **1790** W

	Orientation the Area	Area m²		g-Value (perp. radiation)		Reduction Factor (see Windows worksheet)		Radiation 1 W/m²		Radiation 2 W/m²		P_S 1 W		P_S 2 W
1.	North	11.0	*	0.5	*	0.5	*	10	or	5	=	25	or	13
2.	East	0.0	*	0.0	*	0.4	*	30	or	5	=	0	or	0
3.	South	30.4	*	0.5	*	0.4	*	90	or	10	=	605	or	67
4.	West	2.0	*	0.5	*	0.4	*	35	or	5	=	14	or	2
5.	Horizontal	0.0	*	0.0	*	0.4	*	40	or	10	=	0	or	0

Heat Gain - Solar Heat Load, P_S

Total = **645** or **82**

Internal Heat Load P_I

Spec. Power 1.6 W/m² * A_{TFA} 156 m² = P_I 1: **250** W or P_I 2: **250** W

Heat Gains P_G

$P_S + P_I$ = P_G 1: **894** W or P_G 2: **332** W

$P_L - P_G$ = **1559** or **1459**

Annual Heating Load P_H = **1559** W

Specific Annual Heating Load P_H / A_{TFA} = **10.0** W/m²

Input Max. Supply Air Temperature: 52 °C

Max. Supply Air Temperature $\vartheta_{zu,Max}$: 52 °C

Supply Air Temperature Without Supplementary Heating $\vartheta_{Supply,Min}$: 17.9 °C / 18.1 °C

For Comparison: Heating Load that is Transportable in the Supply Air. $P_{Supply\ Air,Max}$ = 1315 W specific: 8.4 W/m²

Supply Air Heating Sufficient? (Yes/No) **No**

17.9 Evaluation of Group Heating Capacity for Individual Rooms

The PHPP 2007 contains a calculation tool located on the right-hand side of the **Heating Load** worksheet to determine if a critical heating load situation exists for a specific room and if a supplementary heat supply is necessary. This tool has been especially designed for Passive Houses and is not suitable for buildings with higher energy consumptions.

Enter the following information for the room under investigation:

- floor area
- calculated quantities of supply air from the ventilation system
- area of heat transferring building elements and their corresponding U-values adjacent to ambient air, soil, and other adjacent building-units
- information about risk factors (location within the building, thermal separation from neighbouring units, air exchange with neighbouring units, air leakage).

These aspects are used to determine the overall risk factors and the recommended solutions.

Apartment building in Frankfurt, Germany
Photo: Fotostudio Michels

18 "Summer" Worksheet: Calculating the Frequency of Temperatures above the Summer Comfort Limit

Passive Houses have distinguished themselves with high levels of comfort in winter climates. Passive House occupants justifiably demand homes that are comfortable in the summer as well. Comfortable summer temperatures in Passive Houses are no more difficult to obtain than in other buildings, and are generally easier to achieve due to the highly insulated envelope, which makes it easier to keep the building cool during the summer season [PHI 1998/10.]

The summer interior temperature is more dependant on window size, orientation, shading, ventilation, interior heat sources, and most importantly the climatic region, than is annual heat consumption. It is possible to achieve a comfortable summer environment with minimal energy consumption if we consider summer comfort during schematic design. It is therefore recommended to calculate summer comfort for most North American and European zones.

If a building design includes large east or west-facing windows, it is essential to provide the appropriate sun protection measures. Sun protection measures are also recommended for south-facing windows.

Ventilation strategy has a great impact on summer indoor environments. Notably, in climate zones where nighttime temperatures drop to around 20 °C, targeted nighttime ventilation alone is sufficient to flush excess warm air from a building.
Conventional ventilation, by opening windows, is cost efficient and individually controlled. Air exchanges are driven by two mechanisms: wind, and temperature-caused differences in air density.

During the summer prevalent weather conditions include high barometric pressure and little or no wind. In this case, a temperature differential strategy is most effective. Room-high windows are beneficial for this. If interior doors are left open at night, a "chimney effect" spanning several stories has been shown to be particularly effective.

! Advice

> If the ventilation system will be operated at an increased air change rate in the summer, it must be dimensioned for this purpose at the initial design phase. Doubling the rate of air flow while leaving the air duct network unaltered increases power consumption by four to eight times, and adds waste heat from the fan motors to the air.

Under certain circumstances internal heat loads can differ significantly between summer and winter. Examples are variations in lighting use, occupancy, ceiling fans and increased ventilation rates in summer. In general these factors do not need to be individually accounted for; however, if they are to be included in the calculations, a copy of the **IHG** Worksheet can be created for the calculation of summer internal heat gains.

The measure of summer comfort is defined as the frequency with which temperatures rise above the established comfort limit ϑ_{max} expressed as a percentage of time. The default ϑ_{max} used in the PHPP is 25 °C, however different temperatures may be specified for comparison. The lower the frequency with which temperatures exceed ϑ_{max}, the greater the level of comfort. **When the frequency of temperatures in excess of the comfort limit, $h_{\vartheta \geq 25° C}$ exceeds 10 %, additional summer heat protection measures will be necessary.**

The methods applied in the Summer worksheet were developed in 1999. In the intervening time the technique has proved itself for many Passive Houses in Central Europe. There is also a sufficient body of practical experience using these methods with non-residential buildings. However, if high internal heat gains concentrated in time or space occur, a dynamic building simulation may be required to assess comfort during periods of utilization. In consideration of the increasing interest in Passive House in warmer climates, especially in the Mediterranean region as well as the American West and Southwest, the method has being revised and extended as part of the EU project [Passive – On].

The algorithm is based on a dynamic single zone building model that calculates an annual temperature curve for a scenario without active cooling. The temperatures are then sorted by magnitude to produce an annual temperature/duration curve. A line of best fit in the vicinity of the temperature threshold of interest gives the percentage of time in which interior temperatures exceed the desired limit. This method allows determination of the acceptability of the interior temperature without hourly climate data, and with only a small number of entries. However, claims or estimates for individual rooms or tracking of temperatures during the day are not possible.

All building information is shared between the **Annual Heat Demand** sheet and the **Summer** sheet.

As additional data input, the effective thermal storage capacity of the building is required. A default value of 204 Wh/K per meter² of treated floor area is given in the **Summer** worksheet. The guideline to calculate the storage capacity is as follows:

- The minimum value usable for the heat storage capacity is 60 Wh/(m²K).
- For every *massive* surface area (i.e. walls, ceiling, floor) of a typical room in the building a value of 24 Wh/(m²K) is added:

$$c = 60 + n_{heavy} \cdot 24 \text{ [Wh/(m}^2\text{K)]}, \ 0 \leq n_{heavy} \leq 6.$$

For taking the type of summer ventilation into account, additional entries are necessary. At first you are to enter how the air change rate necessary for hygienic reasons is ensured:

- If natural ventilation through windows, or exhaust only mechanical ventilation are planned the corresponding air change rate should be entered in the appropriate cell.
- If a balanced ventilation strategy is planned (mechanical supply-and-extract-air ventilation), the corresponding air change rate should be entered in the "Mechanical Ventilation Summer" cell. In this case, the effect of a sub-soil heat exchanger can be utilized. If no summer bypass of the ventilation system exists, the cell "with HR" is to be marked with an X.

The PHPP considers two alternative possibilities for nightly ventilation strategies:

- Manual nighttime ventilation through windows: the windows are opened during the 12 cooler hours of the day as long as this can lead to a net cooling effect. (During some of this time the outside temperature may exceed the desired temperature). In this case, only the air exchange driven by temperature differences is taken into account because there is often little or no wind during especially hot periods (see comment on **SummVent** worksheet). The temperature dependency of the air exchange rate is taken into account by the algorithm: therefore **an indoor-outdoor temperature difference of 1 K should be used** to determine the air change rate.
- Mechanical automatically regulated ventilation: a constant mechanically driven air exchange is produced, typically using building exhaust fans, when the outdoor temperature is below the indoor temperature.

In both cases, the fact that the indoor temperature may not fall below a minimum value for comfort reasons is taken into account. This value can be entered as well.

Shading factors for the cooling period are calculated dependent upon window orientation in the **Shading-S** worksheet in the same manner as for the heating period.

Overheating frequency, $h_{\vartheta \geq \vartheta max}$ is carried over into the **Verification** worksheet.

The **Summer** worksheet has been developed to be applied to residential Passive House buildings. When large daytime temperature swings occur, especially with inadequate heat protection or high daytime internal loads, an underestimation of the frequency of overheating can result.

Advice

Non-residential buildings are frequently used only during daytime hours. Many office buildings, for example are in use only approximately 2000 hours per year, and schools only about 1000 hours. Because overheating normally occurs during the hours that a building is in use you should strive for a frequency of overheating that is considerably less than 10 %.

Passive House Planning

SUMMER

Climate:	Standard Germany	Interior Temperature:	20 °C
Building:	End-of-Terrace Passive House Kranichstein	Building Type/Use:	Terraced House/Dwellings
Location:	Darmstadt Kranichstein	Treated Floor Area A_{TFA}:	156.0 m²
Spec. Capacity:	204 Wh/K pro m² TFA		
Overheating Limit:	25 °C		

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Red. Factor $f_{T,Summer}$		H_{Summer} Heat Conductance
1.	Exterior Wall - Ambient	A	184.3	*	0.138	*	1.00	=	25.3
2.	Exterior Wall - Ground	B		*		*	1.00	=	
3.	Roof/Ceiling - Ambient	A	83.4	*	0.108	*	1.00	=	9.0
4.	Floor Slab	B	80.9	*	0.131	*	1.00	=	10.6
5.		A		*		*	1.00	=	
6.		A		*		*	1.00	=	
7.		X		*		*	0.75	=	
8.	Windows	A	43.5	*	0.777	*	1.00	=	33.8
9.	Exterior Door	A		*		*	1.00	=	
10.	Exterior TB (length/m)	A	116.9	*	-0.030	*	1.00	=	-3.5
11.	Perimeter TB (length/m)	P		*		*	1.00	=	
12.	Ground TB (length/m)	B	11.4	*	0.061	*	1.00	=	0.7

Exterior Thermal Transmittance, $H_{T,e}$ 64.6 W/K

Ground Thermal Transmittance, $H_{T,g}$ 11.3 W/K

			A_{TFA} m²		Clear Room Height m		m³
Heat Recovery Efficiency η_{HR}	82%	Effective Air Volume V_V	156.0	*	2.50	=	390
SHX Efficiency η^*_{SHX}	93%						

Summer Ventilation continuous ventilation to provide sufficient indoor air quality

Air Change Rate by Natural Ventilation (Windows & Leakages) or Mechanical Ventilation, Summer: 0.20 1/h

Mechanical Ventilation Summer: 0.30 1/h   [ ] with HR (check if applicable)

	$n_{L,nat}$ 1/h		$n_{V,system}$ 1/h		Φ_{HR}			$n_{V,Rest}$ 1/h		1/h
Energetically Effective Airchange Rate n_V	0.200	+	0.300	* (1 -	0.000	)	+	0.000	=	0.500

	V_V m³		$n_{V,equi,fraction}$ 1/h		c_{Air} Wh/(m³K)		
Ventilation Transm. Ambient $H_{V,e}$	390	*	0.221	*	0.33	=	28.4 W/K
Ventilation Transm. Ground $H_{V,g}$	390	*	0.279	*	0.33	=	35.9 W/K

Additional Summer Ventilation for Cooling   Temperature Amplitude Summer 11.7 K

Select: [x] Window Night Ventilation, Manual
[ ] Mechanichal, Automatically Controlled Ventilation

Corresponding Air Change Rate 1/h
(for window ventilation: at 1 K temperature difference indoor - outdoor)

Minimum Acceptable Indoor Temperature 22.0 °C

	Orientation of the Area	Angle Factor Summer		Shading Factor Summer		Dirt		g-Value (perp. radiation)		Area m²		Portion of Glazing		Aperture m²
1.	North	0.9	*	0.92	*	0.95	*	0.50	*	11.0	*	64%	=	2.8
2.	East	0.9	*	1.00	*	0.95	*	0.00	*	0.0	*	0%	=	0.0
3.	South	0.9	*	0.40	*	0.95	*	0.50	*	30.4	*	65%	=	3.4
4.	West	0.9	*	0.94	*	0.95	*	0.50	*	2.0	*	60%	=	0.5
5.	Horizontal	0.9	*	1.00	*	0.95	*	0.00	*	0.0	*	0%	=	0.0
6.	Sum Opaque Areas													0.7

Solar Aperture   Total 7.4   0.05 m²/m²

	Specif. Power q_I W/m²		A_{TFA} m²		W	W/m²
Internal Heat Gains Q_I	2.10	*	156	=	328	2.1

Frequency of Overheating $h_{\vartheta \geq \vartheta_{max}}$ **0.8%** **at the overheating limit ϑ_{max} = 25 °C**

If the "frequency over 25°C" exceeds 10%, additional measures to protect against summer heat waves are necessary.

19 "Shading-S" Worksheet

This worksheet is an auxiliary sheet for the summer. It calculates the corresponding shading factors

r_H: Shading by a neighbouring row of houses

r_R: Shading by window reveals (sides)

r_O: Shading by overhanging horizontal elements above the window, for example balconies

like the **Shading** worksheet (only for summer). All geometrical data to be entered are automatically given from the **Shading** worksheet.

Like in the **Shading** worksheet here it is possible as well, to enter an additional reduction factor r_{other}. This factor can change with the season, for example when the building is shaded by broad-leaved trees. Therefore it is not automatically transferred from the **Shading** worksheet.

As summer shading conditions have a considerable influence on summer comfort, a reduction factor, z, takes temporary window shading devices into account. The temporary summer shading factor can be applied to any window. If this cell is left blank, the calculation uses the value z = 100 % (i.e. no temporary shading).

The reduction factor, z, provides the relation between windows with and without shading devices. gives some typical reduction factors. These are only applicable to low-e triple glazing. For other glazing types the values for shading devices can vary considerably. More accurate specifications can be found for instance in [DIN V 18599-2] or can be obtained directly from the manufacturer. If appropriate it is also possible to determine the shading factors according to DIN EN 13363

Table 10: Reduction Factors for typical temporary shading devices with low-e triple glazing according to DIN V 18599-2

Type of Shading Device	exterior position	interior position
Blinds, vertical lamellas:	0.06	0.7
Blinds, lamellas 45°:	0.1	0.75
Roller blinds / marquees, white	0.24	0.6
Roller blinds / marquees, grey	0.12	0.8
Foil	-	0.6

Practically summer shading devices are oftentimes not used permanently. To take this into account for planning the summer case, using an activation factor of 70 % is suggested, if no automatic control exists which could guarantee a more frequent use.

The reduction factor to be entered in the table has to be calculated in this case as follows:

$$z_{effective} = 0.3 + 0.7 \cdot z$$

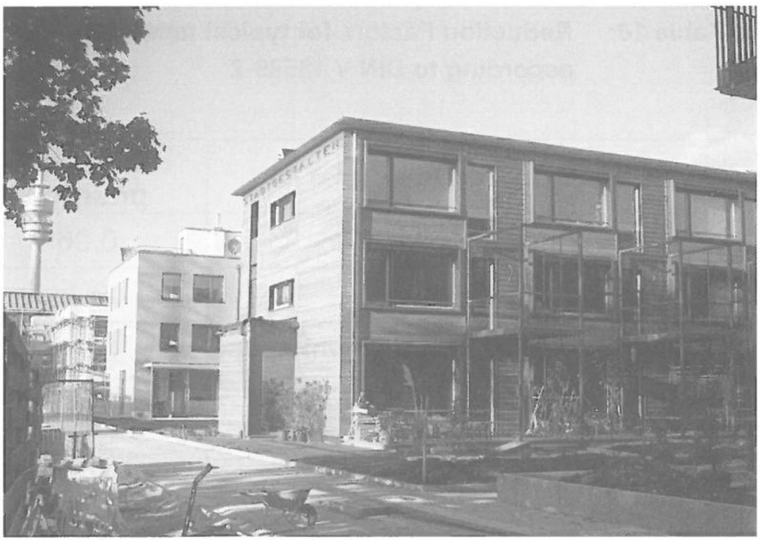
Advice

Automatically controlled sun shading devices are especially helpful in non-residential buildings, which are only temporarily used, because they can minimize solar loads for example during the weekend. When the building is in use, an automatic control frequently leads to complaints. A careful initial start-up and a regular maintenance of such controls is advisable.

The shading factor, r_S, is calculated with,

$$r_S = r_H \cdot r_R \cdot r_O \cdot r_{other} \cdot z$$

The averaged shading factors are weighted for each orientation, and are carried over into the **Summer** worksheet.



Terraced houses in Munich, Germany
Photo: Rainer Vallentin

Passive House Planning

CALCULATING SUMMER SHADING FACTORS

Climate: Standard

Building: End-of-Terrace Passive House Kranichstein

Latitude: 51.3

Summer!

Orien-tation	Glazing Area	Summer Shading Factor
	m²	r_s
North	7.11	92%
East	0.00	100%
South	19.92	40%
West	1.21	94%
Horizontal	0.00	100%

Results from the Summer worksheet:

Frequency of Overheating $h_{\vartheta \geq \vartheta max}$ **0.8%**

Input Field

Quantity	Description:	Deviation from North	Angle of Inclination from the Horizontal	Orientation	Glazing Width	Glazing Height	Glazing Area	Height of the Shading Object	Horizontal Distance	Reveal Depth	Distance from Glazing Edge to Reveal	Overhang Depth	Distance from Upper Glazing Edge to Overhang	Additional Shading Reduction Factor (Summer)	Summer: Temporary Shading Reduction Factor, z	Summer: Horizontal Shading Reduction Factor	Summer: Reveal Shading Reduction Factor	Summer: Overhang Shading Reduction Factor	Total Summer Shading Reduction Factor
		Degrees	Degrees			m		m	m	m	m	m	m	%	%	%	%	%	%
					w_G	h_G	A_G	h_{Hori}	d_{Hori}	o_{Reveal}	d_{Reveal}	o_{over}	d_{over}	r_{other}		r_H	r_R	r_O	r_S
4	S Ground Fl.	180	90	South	0.83	1.81	6.0	10.80	42.50	0.16	0.14	0.43	0.55		50%	91%	92%	93%	39%
4	S Upper Fl.	180	90	South	0.87	1.81	6.3	8.30	42.50	0.16	0.10	0.43	0.55		50%	93%	92%	93%	40%
4	S Attic	180	90	South	0.85	2.24	7.6	5.80	42.50	0.16	0.14	0.43	0.55		50%	95%	92%	94%	41%
2	N Ground Fl.	0	90	North	0.90	1.98	3.6	0.00	0.00	0.16	0.15	0.16	0.15			100%	93%	99%	92%
1	West	270	90	West	0.64	1.89	1.2	0.00	0.00	0.16	0.14	0.16	0.14			100%	95%	99%	94%
2	N Upper Fl.	0	90	North	0.90	1.98	3.6	0.00	0.00	0.16	0.15	0.16	0.15			100%	93%	99%	92%

20 "SummVent" Worksheet: Air Exchange Using Natural Ventilation

The rate of air exchange through open windows is a critical parameter for the summer indoor climate, and is required for assessment in conjunction with the **Summer** worksheet. The calculation tool implemented in the **SummVent** worksheet, allows for an estimate of the air flow rate through specific window opening configurations.

The worksheet calculates the average air change rate for specified ventilation periods and conditions. In the header of each column, enter a textual description for the portion of the air change specified by that column. Because windows do not usually stay open during the entire day, a percentage of the total open time can be entered for the 'Fraction of Opening Duration'. This will be multiplied by the derived air change at the end of the calculation process.

Next, enter the climate boundary conditions. If the window is being used for air exchange all day long (not only for night time cooling,) a typical value of 4 K can be assumed for the temperature difference between interior and exterior. During hot summer periods, wind velocity in many locations is very low. Also, local wind screening by neighbouring buildings has to be accounted for; a reasonable value is 1 m/second. For especially exposed locations a wind speed of 2 m/s can be entered.

For night time temperature driven natural ventilation in the **Summer** worksheet, the air change rate should be calculated at a temperature difference of 1 K, with no wind.

Window specifications should be entered below the Climate Boundary Conditions. When one-sided ventilation through one, or multiple adjacent windows on the same side of the building is being considered, supply information only for **Window Group 1**. When modelling situations with cross ventilation, enter the information for the corresponding window group through which cross flow is achieved under **Window Group 2**. If the window groups are located at different heights in the building, the "chimney effect" is taken into account. In this case the difference in window heights from their centres must also be entered.

The algorithm does not account for flow resistance in the building interior. For cross ventilation, if interior doors obstruct air flow, or if jump ducts or vents are present between window groups, the results should be used with caution.

The calculated air flow rate is derived for both one-sided airflow and cross ventilation. There are situations in which the calculated cross ventilation air flow rate is less than that for the single window case. This can occur when the windows on one side of a building are fully open, and on the same floor the windows on the other side are tilted. In this situation, the cross ventilation air flow rate is the sum of the values for one-sided air flow. The final result for each column is the average air change rate relative to the total volume of the building.

If there are multiple building areas, the air flow rates can be assessed individually and the results summed together. At the bottom of the worksheet a summary section is presented in which the ventilation components may be totalled. In this section the ventilation types, e.g. natural ventilation through windows for fresh air, and night ventilation for building cooling, can be differentiated. These sums can then be linked to the **Summer** worksheet.

Occasionally there are configurations that cannot be calculated using a simple tool like the **SummVent** worksheet. For example, consider a three story building with two tilted and one fully open window on the ground floor, and each upper floor has additional windows that can induce thermal uplift between floors. In this case, calculate the volume of the most important air flow. For this example, enter the cross ventilation from the ground floor to the top story, using the total area of the ground floor operable windows. (The total area of the ground floor windows is the sum of all fully open and tilted windows.) the air exchange rate for windows with one sided airflow in the second story can then be calculated separately and added to the result.

More complex buildings inevitably push the capability of the **SummVent** worksheet to its limit. If the **SummVent** worksheet cannot calculate the airflow rate, then the more precise assessments of multi zone airflow models can be used. Because of uncertainties in the boundary conditions (wind characteristics, pressure coefficient, user behaviour, for example,) such calculations are usually not relevant to the average design practice.

Further details about the underlying calculation algorithms and general information about summer ventilation in Passive Houses are available in German in [AkkP 22].

Passive House Planning

SUMMER VENTILATION

Building:	End-of-Terrace Passive House Kranichstein	Building Type/Use:	Terraced House/Dwellings
Location:	Darmstadt Kranichstein	Building Volume	390 m³

Description	Day GF	Day UF	Night				
Fraction of Opening Duration	13%	50%	50%				
Climate Boundary Conditions							
Temperature Diff Interior - Exterior	4	4	1				K
Wind Velocity	1	1	0				m/s
Window Group 1							
Quantity	4	4	4				
Clear Width	0.84	0.84	0.84				m
Clear Height	1.92	1.92	1.92				m
Tilting Windows?	x	x	x				
Opening Width (for tilting windows)	0.050	0.050	0.050				m
Window Group 2 (Cross Ventilation)							
Quantity			4				
Clear Width			0.84				m
Clear Height			1.92				m
Tilting Windows?			x				
Opening Width (for Tilting Windows)			0.050				m
Difference in Height to Window 1			2.80				m
Single-Sided Ventilation 1 - Airflow Volume	**145**	**145**	**71**	**0**	**0**	**0**	m³/h
Single-Sided Ventilation 2 - Airflow Volume	**0**	**0**	**71**	**0**	**0**	**0**	m³/h
Cross Ventilation Airflow Volume	**145**	**145**	**291**	**0**	**0**	**0**	m³/h
Contribution to Air Change Rate	**0.05**	**0.19**	**0.37**	**0.00**	**0.00**	**0.00**	1/h

Summary of Summer Ventilation Distribution

Description Ventilation Type	Daily Average Air Change Rate	
Nighttime Window Ventilation	0.37	1/h
Daytime Window Ventilation	0.23	1/h
		1/h

Detached house in Münster, Germany
Photo: Thiel

21 "Cooling" Worksheet: Calculation of the Sensible Useful Cooling Demand

The implementation of the algorithms used in the **Cooling, Cooling Units** and **Cooling Load** worksheets are based on the assumption that the principles of heat load minimization in summer are strictly applied. In order to obtain the high energy efficiency of a Passive-House building, sufficient reduction of solar heat loads is particularly important. This can be achieved by using exterior shading devices for the windows, and by installing good insulation or using highly reflective surfaces on walls and roofs. Additionally, to achieve very low values for cooling demand, the internal heat loads must be minimized. Residential buildings designed according to these principles do not require active cooling in most European and North American climate zones.

In the case of a building where an active cooling system is to be installed, the **Cooling** worksheet calculates the *useful* cooling demand. Similar to the annual heating demand, the useful cooling demand represents the amount of heat that must be extracted from the building during the year in order to obtain a comfortable indoor climate. These calculations represent only the *sensible* portion of the cooling energy. This means that energy contributions required for dehumidification or cooling system losses are not yet included.

The calculation algorithm, as in the monthly method, is based on the European standard EN 13790. The functionality is very similar, but the boundary conditions are different. Comparisons of these results to dynamic building simulations show good agreement. In contrast to EN 13790, night time ventilation was also included.

No data entry is required in the **Cooling** worksheet. The building description is carried over from heating demand calculations, and summer case data are carried over from the **Summer** worksheet.

As with the monthly method for the winter case, the monthly summer time energy balance is displayed graphically. Due to storage effects, the individual monthly values do not always agree well with actual cooling demand (as in the winter case).

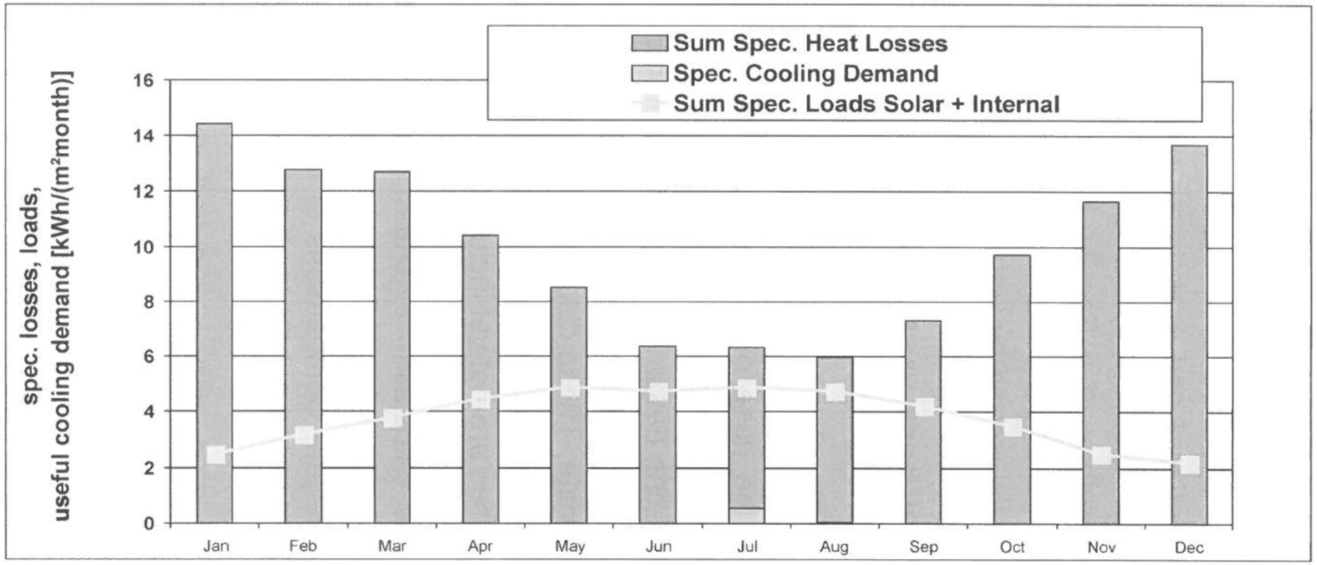
The **Cooling** worksheet has been designed for application to residential Passive Houses. There is not yet sufficient experience for other conditions, such as when high internal heat loads occur during day time hours.

PASSIVE HOUSE PLANNING

SPECIFIC USEFUL COOLING DEMAND MONTHLY METHOD

Climate:	Standard Germany	Interior Temperature:	25 °C
Building:	End-of-Terrace Passive House Kranichstein	Building Type/Use:	Terraced House/Dwellings
Location:	Darmstadt Kranichstein	Treated Floor Area A_{TFA}:	156 m²

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating Degree Hours - Exterior	18.5	16.1	15.5	12.2	9.2	6.4	5.6	6.1	8.1	11.7	14.8	17.6	142	kKh
Heating Degree Hours - Ground	11.2	10.4	11.3	10.5	10.0	8.3	7.9	7.6	8.1	8.9	9.4	10.5	114	kKh
Losses - Exterior	1722	1500	1445	1131	854	597	525	565	755	1093	1376	1637	13199	kWh
Losses - Ground	527	489	535	494	474	392	374	360	383	421	443	496	5387	kWh
Losses Summer Ventilation	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Sum Spec. Heat Losses	14.4	12.7	12.7	10.4	8.5	6.3	5.8	5.9	7.3	9.7	11.7	13.7	119.1	kWh/m²
Solar Load North	28	42	73	104	140	154	154	123	84	50	28	20	1001	kWh
Solar Load East	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solar Load South	99	201	225	283	290	259	272	293	272	215	109	72	2589	kWh
Solar Load West	7	14	21	32	40	39	40	35	27	16	8	5	283	kWh
Solar Load Horiz.	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solar Load Opaque	11	22	31	43	52	50	52	47	38	25	13	8	392	kWh
Internal Heat Gains	244	220	244	236	244	236	244	244	236	244	236	244	2870	kWh
Sum Spec. Loads Solar + Internal	2.5	3.2	3.8	4.5	4.9	4.7	4.9	4.8	4.2	3.5	2.5	2.2	45.7	kWh/m²
Utilisation Factor Losses	17%	25%	30%	43%	58%	74%	75%	80%	58%	36%	22%	16%	38%	
Useful Cooling Energy Demand	0	0	0	0	0	2	88	5	0	0	0	0	96	kWh
Spec. Cooling Demand	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.6**	kWh/m²



22 "Cooling Units" Worksheet: Calculation of the Energy Demand for Space Cooling and Dehumidification

In this worksheet, the latent energy required for dehumidification is determined. This energy demand can arise as either a side-effect of cooling the air or from intentional dehumidification.

The calculation of dehumidification based on monthly average values is difficult, since the underlying processes are, to some extent, extremely non-linear. On the other hand, changes in the humidity content of building structures occur on timescales of months, so that short-term humidity fluctuations can be compensated by storage effects. Since dehumidification can have a significant impact on the energy demand, this worksheet has been included on a trial basis.

Four different processes are considered. Besides the calculation of latent energy demand, the user can declare in this sheet whether air conditioning devices are present and thereby if they should be included in the primary energy balance. The worksheet calculates the portion of the entire cooling demand (both sensible and latent) that each AC device covers.

For the humidity level of the building, it is important to know if the ventilation unit recovers humidity (for example, in heat wheels or energy recovery units with humidity recovery). If so, the average humidity recovery rate during the cooling period should be entered in the corresponding cell. Humidity recovery reduces both the humidity gain from and humidity loss to the outside. Depending on the outside climate, this can either reduce or increase the humidity content of the room air.

22.1 Supply Air Cooling

In climatic regions, in which the removal of heat cannot be achieved via passive cooling, it is possible to maintain a comfortable indoor temperature simply by cooling the supply air. This supply air is, in any case, required to maintain a sufficient air quality. In order to achieve this, the transparent and opaque building envelope components must be well shaded from the sun, the internal gains must be minimised, and the amount of insulation should be appropriate for the temperature difference in the summer.

! Frequent Mistake

> Ventilation units in a Passive House serve primarily to guarantee a high air quality. The cooling power of supply air cooling is not comparable to standard air conditioning systems. The maximum cooling load that can be delivered by the supply air in residential buildings is approximately 8 W/m^2.

In case the supply air is cooled, the appropriate field should be marked with an "x".

The majority of commercially available split units work on the On/Off principle: The compressor runs at full load until some threshold temperature is reached and then it turns off. The cycle begins anew as soon as a second threshold temperature is reached. For this type of operation, the field "Cycle Operation" should be marked with an "x". If the cooling coil in the supply air is continuous controllable (via a controllable compressor in split units or, for example, by fan coils with thermostat control), then this field should not be marked with an "x".

Finally, the average temperature of the cooling surface at full load must be entered. If the A/C unit is run until frost forms on the coil and then shut off, allowing the frost to melt, the minimum temperature is 0°C. When coupled to a water-chiller, a higher temperature should be entered.

The supply air flow rate is taken from the **Summer** worksheet.

22.2 Recirculation Cooling

Conventional air-cooled units work mainly with recirculating air. Air from the plant room is drawn via an extra ventilator, cooled down, and blown back into the room. If such a device is installed the force-air circulation area must be filled in.

The necessary inputs are the same as those for the supply air cooling. Additionally, the circulation air flow rate is required.

22.3 Surface Cooling

If no air conditioning unit is present or the cooling capacity of the above inputted unit is insufficient, surface cooling (for example, via thermally activated concrete ceilings) can be marked with an "x". The load that is not covered by air cooling can then be covered by surface cooling, without additional condensation forming.

22.4 Extra Dehumidification

It is assumed that there is an upper limit to the absolute humidity which is considered comfortable, even at lower air temperatures. This value is given in ISO 7730 and ASHRAE 55 as 12 g per kg of dry air. Therefore, in climates that are very humid in the summer, dehumidification of the air might be necessary, even when the room temperature remains in a comfortable range.

The following data are required:

Target value for the room humidity: A value of 12 g/kg is recommended. This corresponds to a dew point of approx. 17 °C.

Sources of Humidity: A typical value for the humidity production caused by the utilization in residential buildings is 2 g water per square meter and hour.

Humidity Capacity of the Building: This concerns the amount of water per square meter that the building can absorb per 1 g/kg change in the absolute humidity. This value depends strongly on the construction of the inner and outer building components. Since solid components absorb less humidity per kg than wood, the absorption capabilities of solid and lightweight structures does not differ very much. For typical structures in residential buildings, a value of 700 g/(g/kg)/m^2 can be entered.

5 Terraced houses in Aachen, Germany
Photo: Linie4 Architekten

Passive House Planning

COMPRESSOR COOLING UNITS

Climate: Standard Germany
Building: End-of-Terrace Passive House Kranichstein
Location: Darmstadt Kranichstein

Interior Temperature Summer: 25 °C
Building Type/Use: Terraced House/Dwellings
Treated Floor Area A_{TFA}: 156.0 m²

	A_{TFA} m²		Clear Room Height m		m³
Effective Air Volume V_V	156	*	2.50	=	390

	$n_{V,system}$ 1/h		Φ_{HR} Efficiency Humidity Rec.			1/h
Hygrically Effective Mech. Air Change Rate Summer	0.300	* (1 -		)	=	0.300

	$n_{V,nat}$ 1/h		$n_{V,Res}$ 1/h		$n_{Night,Windows}$ 1/h		$n_{Night,mechanical}$ 1/h		
Direct Ambient Air Change Rate Summer	0.200	+	0.000	+	0.000	+	0.000	=	0.200

Ambient Air Change Rate Summer — Total 0.50 1/h

Supply Air Cooling
check as appropriate

On/Off Mode (check as appropriate)	x	
Minimum Temperature of Cooling Coil Surface	0	°C

Recirculation Cooling
check as appropriate

On/Off Mode (check as appropriate)	x	
Minimum Temperature of Cooling Coil Surface	10	°C
Volume Flow Rate	300	m³/h

Additional Dehumidification
check as appropriate

Max. Humidity Ratio	12	g/kg
Humidity Sources	2	g/(m²h)
Humidity Capacity Building	700	g/(g/kg)/m²
Humidity at Beginning of Cooling Period	8	g/kg

Panel Cooling
check as appropriate

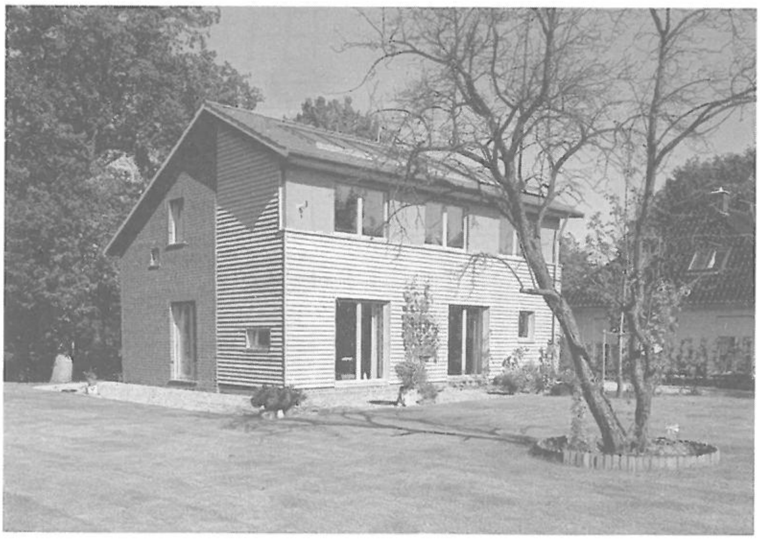
	sensible	latent		Sensible Fraction
Useful Cooling Demand	0.6	0.0		
of which				
Supply Air Cooling			kWh/(m²a)	
Recirculation Cooling			kWh/(m²a)	
Dehumidification			kWh/(m²a)	
Remaining for Panel Cooling			kWh/(m²a)	
Total	0.0	0.0	kWh/(m²a)	0.0%
Unsatisfied Demand	0.6	0.0	kWh/(m²a)	

23 "Cooling Load" Worksheet: Average Daily Cooling Load

This worksheet is analogous to the **Heating Load** worksheet. An energy balance of internal and solar loads, conduction and ventilation losses or gains for the design day provides the cooling capacity required to keep a Passive House (i.e. a house with an extremely low cooling demand) cool on this day.

The calculation results represent a daily average of the cooling capacity for the design day. The use of daily average values presumes that building mass can buffer the fluctuations of the internal and solar loads during the day. As for residential buildings with sufficient sun shading, this is generally the case.

In the last row of the **Cooling** worksheet, the daily temperature fluctuation caused by the solar gains during the design day is calculated. This value should not exceed 3 K; otherwise the calculated cooling load might not be enough. In this case, a detailed procedure for calculating the load should be used. The same applies to buildings, in which high internal gains during day cause high temperature fluctuations (for example, high occupancy, light construction offices or schools).



Detached house in Wardenburg, Germany
Photo: team 3

Passive House Planning

COOLING LOAD

Building:	End-of-Terrace Passive House Kranichstein	Building Type/Use:	Terraced House/Dwellings
Interior Temperature:	25 °C		
Location:	Darmstadt Kranichstein	Treated Floor Area A_{TFA}:	156.0 m²
Spec. Capacity:	204 Wh/(m²K) (Enter in "Summer" worksheet.)	Climate (Cooling Load):	Nord- und westdeutsches Tiefland, z.B. Hannover

	Ambient Air	Sky	Ground	Radiation: North	East	South	West	Horizontal
Design Temperature:	24.0 °C	14.2 °C	14.7 °C	100	180	200	180	330 W/m²

	Building Elements	Temperature Zone	Area m²		U-Value W/(m²K)		Factor Always 1 (except "X")		TempDiff K		W
1.	Exterior Wall - Ambient	A	184.3	*	0.138	*	1.00	*	-1.0	=	-25
2.	Exterior Wall - Ground	B		*		*	1.00	*	-10.3	=	
3.	Roof/Ceiling - Ambient	A	83.4	*	0.108	*	1.00	*	-1.0	=	-9
4.	Floor Slab	B	80.9	*	0.131	*	1.00	*	-10.3	=	-109
5.		A		*		*	1.00	*	-1.0	=	
6.		A		*		*	1.00	*	-1.0	=	
7.		X		*		*	0.75	*	-1.0	=	
8.	Windows	A	43.5	*	0.777	*	1.00	*	-1.0	=	-34
9.	Exterior Door	A		*		*	1.00	*	-1.0	=	
10.	Exterior TB (length/m)	A	116.9	*	-0.030	*	1.00	*	-1.0	=	3
11.	Perimeter TB (length/m)	P		*		*	1.00	*	-10.3	=	
12.	Ground TB (length/m)	B	11.4	*	0.061	*	1.00	*	-10.3	=	-7
13.	House/Apartment Party Wall	I	84.8	*	0.375	*	1.00	*	3.0	=	96
			$L_{ambient}$ W/K		TempDiff K		L_{Sky} W/K		TempDiff K		
14.	Radiation Correction		-2.7	*	-1.0	+	2.6	*	-10.8	=	-26

Transmission Heat Losses P_T Total = **-110**

Ventilation System:

	A_{TFA} m²		Clear Room Height m		m³
Effective Air Volume, V_V	156.0	*	2.50	=	390

	Vent. Transm. W/K		TempDiff kKh/a		W
Exterior	28.4	*	-1.0	=	-28
Ground	35.9	*	-10.3	=	-368

Additional Summer Ventilation:

- [x] Window Night Ventilation, Manual
- [ ] Mechanical, Automatically Controlled Ventilation

Corresponding Air Change Rate: 0.00 1/h
Minimum Indoor Temperature: 22.0 °C

		kWh/d		kh/d		W
Heat Removal Cooling Design Day	Window Ventilation	0.0	/	0.024	=	0
(from Cooling worksheet)	Automatic Night Ventilation	0.0	/	0.024	=	0

Ventilation Heat Load P_V Total = **-397** W

	Orientation of the Area	Area m²		g-Value (perp. radiation)		Reduction Factor		Radiation W/m²		P_S W
1.	North	11.0	*	0.5	*	0.51	*	100	=	281
2.	East	0.0	*	0.0	*	0.40	*	180	=	0
3.	South	30.4	*	0.5	*	0.22	*	200	=	681
4.	West	2.0	*	0.5	*	0.48	*	180	=	87
5.	Horizontal	0.0	*	0.0	*	0.40	*	330	=	0
6.	Sum Opaque Areas									114

Heat Gain - Solar Heat Load, P_S Total = **1163**

	Spec. Power W/m²		A_{TFA} m²		P_I W
Internal Heat Load P_I	3.1	*	156	=	**484**

Cooling Load P_C $P_T + P_V + P_S + P_I$ = **1139** W

Specific Maximum Cooling Load P_C / A_{EB} = **7.3** W/m²

	Solar Load W		Time h/d		Spec. Capacity Wh/(m²K)		A_{TFA} m²		
Daily Temperature Swing due to Solar Load	1162.7	*	24	/ (	204	*	156	) =	**0.9** K

24 "DHW+Distribution" Worksheet: Calculating the Heat Losses through Plumbing

This worksheet calculates the heat losses of the distribution system for space heating and DHW. The worksheet allows you to include individual piping segments located in different temperature zones (e.g. interior living space, basement, below ground, etc.).

The heat loss coefficients Ψ for the distribution lines can be determined using the secondary calculation on this worksheet (see Figure 22).

	Nominal Width	240	mm
	Insulation Thickness:	100	mm
	Reflective? Please mark with an "x"!		
x	Yes		
	No		
	Thermal Conductivity	0.035	W/(mK)
	$\Delta\vartheta$	30	K
	Interior Pipe Diameter:	0.24000	m
	Exterior Pipe Diameter	0.24225	m
	Exterior Pipe Diameter	0.44225	m
	α–Surface	2.72	W/(m²K)
	Ψ-Value	**0.333**	**W/(mK)**
	Surface Temperature Difference	0.000	K

Figure 22: Secondary calculation for determining the Ψ-value for distribution pipes (example)

Secondary Calculation Storage Losses		
Specific Heat Losses Storage (total)	3.0	W/K
Typical Temperature DHW	60	°C
Room Temperature	20	°C
Total Storage Heat Losses	120	W

Figure 23 Secondary calculation for storage tank losses (example)

24.1 Space Heat Distribution

The heat losses of the distribution system for the space heating are calculated in this section. The annual heat demand, determined using either the annual or monthly calculation method, as selected on the **Verification** worksheet, is the basis for the calculated losses. The design flow temperature and the design system heating load are additional input values on this worksheet.

The total pipe length located within the thermal envelope is to be entered in the first column. The heat lost through these pipes can act as an internal heat source.

Therefore a portion of the emitted heat is assumed to reduce the annual heat demand and is thus not counted as a heat loss during the heating period.

The second and third columns are for pipe segments that are located outside of the thermal envelope, so that the heat loss from these is not usable as an internal heat source.

As a result, the annual heat losses and the efficiency of the heat distribution system are given.

24.2 Heat Demand for Domestic Hot Water

The domestic hot water (DHW) demand of 25 litres per person per day at 60 °C is a standard value used for residential buildings meeting the Passive House standard. The hot water demand for washing machines and dishwashers connected to the hot water distribution system is also explicitly provided.

24.3 Domestic Hot Water Distribution and Storage

24.3.1 Circulation

If there are pipes with constant pump-driven hot water circulation, enter the length and heat loss coefficient of the pipe, the design flow temperature, the daily operating hours, and the temperature of the space within which the pipes are located. The design room temperature in each column also applies to the individual pipe lengths and the storage tank in that column.

As with the space heat distribution calculation, the pipes located within the thermal envelope should be entered in the first column. The second and third columns are intended for pipes and storage tanks located outside the thermal envelope.

24.3.2 Individual Pipes

For the calculation of the heat losses for individual pipes (or branch pipes, in contrast to the circulation pipes of section 24.3.1) enter their lengths and outside diameters. The overall length of the individual runs is the sum of all the sections from the beginning of the branch pipe to the tapping point. If sections of a run are shared by several tapping points, they must be counted multiple times. This applies regardless of the number of dwelling units within the building.

The heat losses of the individual runs or branch pipes are calculated based on the assumption that each inhabitant of a dwelling unit uses each hot water tap of this unit three times a day and that the line between the tapping point and the storage tank or circulation pipe cools down completely between each use. Generally it is not necessary to insulate individual runs, since this retards but doesn't prevent the cooling of the pipe, so that the line will have to be emptied completely at the next use anyway. However, if the pipe is insulated, enter the outside diameter of the un-insulated pipe.

In special cases, particularly in certain non-residential buildings, it may occur that the number of tap uses cannot be determined based on the number of people per dwelling unit or that, because of the high number of tap uses, the distribution lines don't cool off completely between each use. This will cause the losses of the individual runs to be overestimated considerably. In such cases the calculation may be modified as appropriate, in consultation with the certifying agency.

24.3.3 Storage

The heat loss values for storage tanks should be taken from the following table or from testing certificates:

Table 11: Heat Loss Values of Hot Water Storage Tanks in Watts; ϑ_{HW} = 55 °C, ϑ_{amb} = 20 °C

Storage Volume	Poorly Insulated approx. 2 cm	Moderately Insulated approx. 5 cm	Well Insulated approx. 10 cm
Litres	Watt	Watt	Watt
25	54	30	20
50	83	45	29
75	107	57	37
100	128	68	43
150	165	86	54
200	199	103	64
300	257	131	80
500	357	180	108
750	464	231	137
1000	559	276	162
1500	727	356	207
2000	877	427	247

If the storage tank temperature, ϑ_{HW}, is higher or the ambient temperature of the mechanical room, ϑ_{Amb}, differs from the values used in the table, then the hot water storage tank losses can be converted using the following formula:

$$Q_{New} = Q_{Stor,55/20} \cdot \frac{\vartheta_{HW} - \vartheta_{amb}}{(55\text{-}20)\ K}$$

Frequently the hot water storage tank losses are much higher than indicated due to poor installation of the insulation blanket and poor insulation of the storage tank connections and other fittings.

Under 'Secondary Calculation Storage Losses', a formula is given that calculates the actual heat losses of a DHW storage tank based on the heat loss coefficient from the testing certificates (typically 2-3 W/K). See Figure 23.

The results are the annual heat losses of the DHW system and the efficiency of the hot water distribution system including hot water storage as well as the useful fraction of the waste heat of the DHW system as an interior heat gain.

Gym in Heidelberg-Kirchheim, Germany

Photo: Passive House Institute

Apartment building in Ludwigshafen, Germany
Photo: Passive House Institute

Passive House Planning

HEAT DISTRIBUTION AND DHW SYSTEM

Building:	End-of-Terrace Passive House Kranichstein	
Location:	Darmstadt Kranichstein	
Interior Temperature:	20	°C
Building Type/Use:	Terraced House/Dwellings	
Treated Floor Area A_{TFA}:	156	m²
Occupancy:	4.5	Pers
Number of Residences:	1	
Annual Heat Demand $q_{Heating}$:	2112	kWh/a
Length of Heating Period:	225	d
Average Heat Load P_{ave}:	0.4	kW
Marginal Utilisability of Additional Heat Gains:	73%	

			Parts: Warm Region	Cold Region		Total		
Space Heat Distribution			1	2	3			
Length of Distribution Pipes	L_H	(Project)	13.50				m	
Heat Loss Coefficient per m Pipe	Ψ	(Project)	0.140				W/(mK)	
Temperature of the Room Through Which the Pipes Pass	ϑ_X	Mechanical Room	20				°C	
Design Flow Temperature	ϑ_{dist}	Flow, Design Value	55.0				°C	
Design System Heat Load	$P_{heating}$	(exist./calc.)	2.0				kW	
Flow Temperature Control (check)			x					
Design Return Temperature	ϑ_R	$=0.714*(\vartheta_{dist}-20)+20$	45.0				°C	
Annual Heat Emission per m of Plumbing	q^*_{HL}	$=\Psi\,(\vartheta_m-\vartheta_X)\,t_{Heating}*0.024$	7			Total 1,2,3	kWh/(m·a)	
Possible Utilization Factor of Released Heat	η_G		73%				-	
Annual Losses	Q_{HL}	$=L_H \cdot q^*_{HL} \cdot (1-\eta_G)$	25	0	0	25	kWh/a	
Specif. Losses	q_{HL}	$=\Sigma Q_{HL} / A_{TFA}$					kWh/(m²a)	0.2
Utilisation Factor of Space Heat Distribution	$h_{a,HL}$	$=q_H / (q_H + q_{HL})$				99%	-	

			Total		
DHW: Standard Useful Heat					
DHW Consumption per Person and Day (60 °C)	V_{DHW}	(Project or Average Value 25 Litres/P/d)	25.0	Litre/Person/d	
Average Cold Water Temperature of the Supply	ϑ_{DW}	Temperature of Drinking Water (10°)	10.0	°C	
DHW Non-Electric Wash and Dish		(Electricity worksheet)	321	kWh/a	
Useful Heat - DHW	Q_{DHW}		2680	kWh/a	
Specif. Useful Heat - DHW	q_{DHW}	$=Q_{DHW} / A_{TFA}$		kWh/(m²a)	17.2

DHW Distribution and Storage			Warm Region	Cold Region		Total		
Length of Circulation Pipes (Flow + Return)	L_{HS}	(Project)	13.5	2.0			m	
Heat Loss Coefficient per m Pipe	Ψ	(Project)	0.140	0.140			W/m/K	
Temperature of the Room Through Which the Pipes Pass	ϑ_X	Mechanical Room	20	11.0			°C	
Design Flow Temperature	ϑ_{dist}	Flow, Design Value	60.0	60.0			°C	
Daily circulation period of operation.	td_{Circ}	(Project)	18.0	18.0			h/d	
Design Return Temperature	ϑ_R	$=0.875*(\vartheta_{dist}-20)+20$	55	55			°C	
Circulation period of operation per year	t_{Circ}	$=365\ td_{Circ}$	6570	6570			h/a	
Annual Heat Released per m of Pipe	q^*_Z	$=\Psi\,(\vartheta_m-\vartheta_X)\,t_{Circ}$	34.5	42.8			kWh/m/a	
Possible Utilization Factor of Released Heat	η_{GDHW}	$=t_{heating}/365d * \eta_G$	44.8%	0.0%			-	
Annual Heat Loss from Circulation Lines	Q_Z	$=L_{HS} \cdot q^*_Z \cdot (1-\eta_{GDHW})$	257	86		343	kWh/a	
Total Length of Individual Pipes	L_U	(Project)	9.00				m	
Exterior Pipe Diameter	d_{U_Pipe}	(Project)	0.012				m	
Heat Loss Per Tap Opening	$q_{Individual}$	$=(c_{pH2O}V_{H2O}+c_{pMat}V_{Mat})(\vartheta_{dist}-\vartheta_X)$	0.0322				kWh/tap opening	
Occupancy Coefficient	n_{Tap}	$=n_{Pers} \cdot 3 \cdot 365 / n_{LU}$	4881				Tap openings per year	
Annual Heat Loss	q_U	$=n_{Tap} \cdot q_{individual}$	157.2				kWh/a	
Possible Utilization Factor of Released Heat	η_{G_U}	$=t_{heating}/8760*\eta_G$	44.8%				-	
Annual Heat Loss of Individual Pipes	Q_U	$=q_U \cdot (1-\eta_{G\_U})$	86.8			87	kWh/a	
						Total 1,2,3		
Average Heat Released From Storage	P_S			98			W	
Possible Utilization Factor of Released Heat	η_{G_S}	$=t_{heating}/8760*\eta_G$		0.0%			-	
Annual Heat Losses from Storage	Q_S	$=P_S \cdot 8.760\ kh \cdot (1-\eta_{G\_S})$		857.8		858	kWh/a	
						Total 1,2,3		
Total Heat Losses of the DHW System	Q_{WL}	$=Q_Z+Q_U+Q_S$				1287	kWh/a	
Specif. Losses of the DHW System	q_{WL}	$=Q_{WL} / A_{TFA}$					kWh/(m²a)	8.3
Utilisation Factor DHW Distrib and Storage	$\eta_{a,WL}$	$=q_{TWW} / (q_{TWW} + q_{WV})$				67.6%	-	
Total Heat Demand of DHW system	Q_{gDHW}	$=Q_{DHW}+Q_{WL}$				3967	kWh/a	
Total Spec. Heat Demand of DHW System	q_{gDHW}	$=Q_{gDHW} / A_{TFA}$					kWh/(m²a)	25.4

25 "Solar DHW" Worksheet: Calculating the Total Heat Contribution from the Solar Thermal System to the DHW Supply

The algorithm for calculating the solar contribution has been revised completely in the PHPP 2007. Now the solar contribution of a typical system for solar DHW generation, as it is common for detached homes or smaller apartment buildings, can be calculated. The greatest difference to the former PHPP is that not only the inclination of the collector panel, but also it's orientation and shading (if applicable) depending on the geographic or meteorological location, respectively, can be taken into account.

The following parameters are taken into account in the new version:

- Solar collector area: thermal specifications of the solar collector, available from the manufacturers or from test certificates. A list of solar collectors has been provided. Individual entries in the list are possible.
- Volume and thermal specifications of the DHW storage tank: Also from manufacturer's information in the list of solar DHW storage tanks. Individual entries are possible.
- Energy demand for DHW supply depending on the occupancy of the building. This value is derived from the **DHW+Distribution** worksheet.
- Solar irradiation on the collector surface: depending on the orientation (in reference to north) and the inclination of the collector surface. The irradiation values are given from the **Climate Data** worksheet as average monthly values (kWh/(m²a)) depending on the location or the climate region, respectively.
- Shading of the collector surface: by the horizon or by semi-transparent objects (e.g. trees), respectively, depending on the location; similar to the **Shading** worksheet (Windows), for more information see the chapter for **Shading**.

The solar contribution rate is calculated with an algorithm according to Duffie and Beckman [Duffie/Beckman]. Please note that this method is only a rough estimate. However, the accuracy is normally sufficient for sizing a solar thermal system (collector area and storage tank volume) and to estimate the yield of the system under the boundary conditions mentioned above. For more accurate calculations a thermal simulation becomes necessary. This is appropriate especially for the detailed dimensioning of large solar thermal systems for apartment houses with special hydraulic systems (buffer storage tanks etc.).

The heat losses in the solar circuit and the heat losses of the solar fraction of the DHW storage tank, i.e. of the lower part of the storage volume, which is only heated by the solar thermal system, are taken into account and are part of the calculation for the solar thermal system contribution rate. The heat losses of the stand-by fraction of the storage tank, that means of the upper part of the storage tank volume, which is heated, if necessary by the boiler, are given as the value "Heat losses from storage", which can be used for further calculations of the heat demand of the DHW system in the **DHW+Distribution** worksheet. Depending on the installation location of the storage tank, this value should be transferred to the corresponding cells ("Average Heat Released from Storage", P_s) in the **DHW+Distribution** worksheet or linked there, respectively.

The distinction between stand-by part (upper part) and solar part (lower part) is only valid if the storage tank has a distinct thermal stratification. This is generally the case with high-quality solar storage tanks. In simpler DHW storage tanks (without thermal stratification) the entire volume has almost the same temperature. In this case the higher heat loss coefficient [W/K], which gives the heat losses when the storage tank is fully loaded, always must be used. The "Secondary Calculation Storage Losses" in the **DHW+Distribution** worksheet always uses this higher value, which should only be overwritten if a stratified solar storage tank is used.

For dimensioning a solar thermal system the following rule of thumb applies:

A small solar thermal system with an annual solar contribution rate of not more than 50 % is generally the most economic choice. When facing south this can be achieved with a solar collector area of about 1 m^2 / person. The solar storage tank should have a volume of 70-100 litres per person. In apartment houses this value can generally be considerably smaller (0.5 m^2 and 50 litres / person)

The reason for this recommendation is that a higher solar thermal contribution rate during the winter months can only be achieved with considerably larger collector areas (2 m^2 / person). During the summer months, however, the usability of the solar yields by the DHW demand of the users is fairly restricted. This means that thermal solar systems with large collector areas often overheat in summer, because the solar storage tank cannot absorb the high heat yield anymore. This is called stagnation. Technically this is not critical, however, this lowers the life expectancy of the heat carrier medium in the solar circuit (mixture of water and glycol) which increases the maintenance costs of the system. To a smaller extent this effect can be mitigated, if the inclination of the solar collector is increased. This lowers the solar radiation level in summer (high inclination angle of the sun, less overheating). On the other hand you get higher yields in winter. In the chart the monthly solar thermal yields and the monthly solar thermal contribution are displayed, so that you can identify the effect of a change in inclination instantly.

If a perfect south orientation of the collector (180°) is not possible, the solar collector area can, if necessary, be enlarged, until the solar thermal contribution rate increases to about 50 %. This allows for satisfactory solar thermal contribution rates, even with east or west facing roof surfaces.

Passive House Planning

HOT WATER PROVIDED BY SOLAR

Building:	End-of-Terrace Passive House Kranichstein	Building Type/Use:	Terraced House/Dwellings	
Location:	Darmstadt Kranichstein	Treated Floor Area A_{TFA}:	156.0	m²

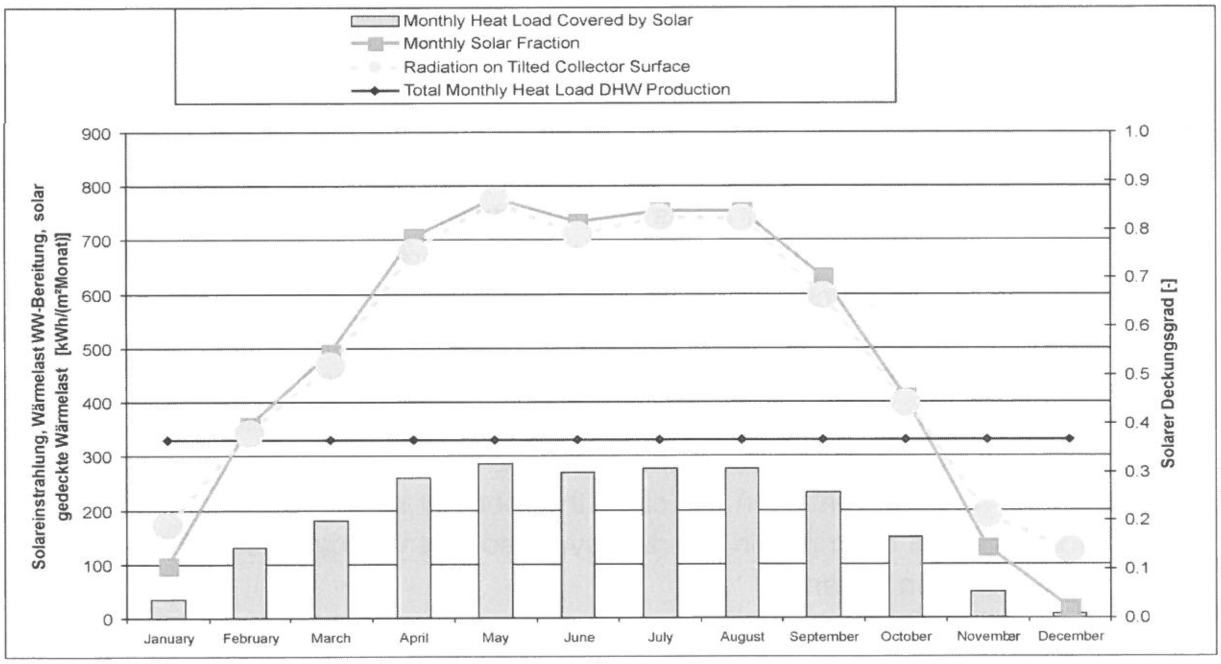
Solar Fraction with DHW Demand including Washing and Dish-Washing

Heat Demand DHW	q_{gDHW}	3967	kWh/a	from DHW+Distribution worksheet
Latitude:		51.3	°	from Climate Data worksheet
Selection of collector from list (see below):		7	Selection:	7 Improved Flat Plate Collector FF
Solar Collector Area		5.30	m²	
Deviation from North		180	°	
Angle of Inclination from the Horizontal		45	°	
Height of the Collector Field		1	m	
Height of Horizon	h_{Hori}		m	
Horizontal Distance	a_{Hori}		m	
Additional Reduction Factor Shading	r_{other}		%	
Occupancy		4.5	Persons	
Specific Collector Area		1.2	m²/Pers	

Estimated Solar Fraction of DHW Production	**54%**			
Solar Contribution to Useful Heat	**2155**	kWh/a	**14**	kWh/(m²a)

Secondary Calculation of Storage Losses

Selection of DHW storage from list (see below):	12	Selection:	12 Improved Solar Storage
Total Storage Volume	490	litre	
Volume Standby Part (above)	147	litre	
Volume Solar Part (below)	343	litre	
Specific Heat Losses Storage (total)	3.3	W/K	
Typical Temperature DHW	60	°C	
Room Temperature	20	°C	
Storage Heat Losses (Standby Part Only)	**98**	W	
Total Storage Heat Losses	**132**	W	



26 "Electricity" Worksheet: Calculating the Electricity Demand

The total electricity energy demand takes into consideration all the energy services normally provided by electricity including all auxiliary energy. Excluded are the services for DHW, e.g., electricity for heat pumps or for flow-type electric hot water heaters which are calculated in the **PE Value** worksheet. Auxiliary energy and household appliances are treated separately. Auxiliary energy is handled within the **Aux Electricity** worksheet. The first step in order to estimate the electric energy demand of residential buildings is to select "Residential" from the drop-down menu "Building Type" in the **Verification** worksheet. The electric energy balance of non-residential buildings is calculated in the **Electricity Non-Dom** worksheet.

26.1 Setting Goals and Requirements

The electricity demand in Passive Houses should be reduced as significantly as possible in order to achieve the primary energy requirement of $\mathbf{q_p \leq 120\ kWh/(m^2a)}$. See Chapter 29.4.

The efficiency of household appliances and building systems is crucial for reduction of future electrical demands. Efficiency is characterized by standardized energy usage estimates. The electricity demand is calculated from these estimates and the conditions of use.

In order to verify that the primary energy requirement has been met, standard operating conditions are chosen with regards to equipment and efficiency, that allow calculation of average electrical usage. These conditions are found in the **Electricity** worksheet and are formatted as fixed values. The following factors are influencing variables as well: Number of occupants, treated floor area and reference volume (treated floor area x average room height). These values are carried over from the previous worksheets.

The electricity demand is strongly influenced by the number of occupants. In order to specify the number of occupants utilized on the **Electricity** worksheet one of the following methods must be chosen on the **Verification** worksheet:

- In order to calculate using the value entered under 'Planned Number of Occupants', the 'Design' method must be selected in the adjacent field.
- If a calculation based on Treated Floor Area is desired to indicate standard occupancy levels the 'Verification' method should be selected.

Some of the listed services can be provided completely or partially using non-electrical energy sources, e.g., gas cooking ranges and gas clothes dryers, DHW demand for washing machines and dishwashers with DHW connections. The total electricity demand and the primary energy demand for the appliances and services listed are calculated entirely in the **Electricity** worksheet, independent of how the DHW is supplied. The energy needed for space heating and DHW is not considered, even if it is provided by electricity. The total of the electricity demand is shown in the second to last line of the worksheet. It is then divided by the treated floor area. The results of this worksheet are the specific electricity demand and the non-electrical demand. They are found in the bottom row of the worksheet. The primary energy demand for each application is calculated in the last column (column 14).

For the services presented on this worksheet, the recommended maximum values for Specific Electricity and Energy Demand are given below as a function of the Treated Floor Area, however the overall energy balance must comply with the primary energy requirement as calculated on the **PE Value** worksheet:

Recommended Specific Electricity Demand: 18 kWh/(m²a)

Recommended Specific Primary Energy Demand for Electricity: 50 kWh/(m²a)

26.2 Domestic Electricity Demand Calculation Procedure

The procedures presented in the following section are for estimating the domestic electricity demand, and other energy demands which may typically be supplied by electrical service. Excluded are any space heating and DHW applications, even if provided by electricity.

The annual electricity demand E_{el}, is calculated for every service using the following formula (column 9):

$$E_{el} = s \cdot V_{norm} \cdot f_{use} \cdot h \cdot G \cdot f_{el}$$

s — Column 1: Indicate if the appliance or service exists. 1 = Yes, 0 = No. In general, the values 0 or 1 are used for single households. For buildings with multiple residences, i.e. corresponding value in the **Verification** sheet > 1, the fraction ($0 < s < 1$) of apartments or households containing the appliance or service is entered.

column 2: Indicate if the appliance or service is located within the thermal envelope. 1 = Yes, 0 = No; e.g. this can influence the electricity demand of refrigerators and freezers.

V_{norm} — column 3: Standard energy consumption of the appliance. See Chapter 26.3. for a definition of each service. V_{Norm} is the value from the energy efficiency label.

f_{use} column 4: Utilization factor for correction of the standard energy consumption. Standard value: 1.

h column 5: Frequency of use per annum and per reference size (see each service for definitions.) These sizes are standard values in the verification process and should not be altered.

G column 6: Reference value for "h" (column 5), i.e.: number of occupants or households (for standard occupancy: 1)

f_{el} column 8: Electrical portion of the service, excluding any electricity for DHW. For most services f_{el} is 1. In this case, the calculated useful energy in Column 7 is the electricity demand.

The electricity demand from Column 9 is summarized in the second to last row.

In the last row, the specific electricity demand is found using the following formula:

$$e_{el} = \frac{E_{el}}{A_{TFA}}$$

A_{TFA} row 6: treated floor area (heated living area or usable floor area)

If all listed energy services are supplied exclusively by electricity, the calculation is for the most part finished with column 9. The total electricity and final energy demands are the sum of all services. This value, multiplied by the primary energy factor of electrical service, determines the non-renewable primary energy demand., (from Gemis 4.2, **2.6 kWh/kWh**. See below).

If a portion of the service is delivered partially or wholly by non-electrical energy e.g., clothes washing and drying, dishwashing, or cooking (see Chapter 26.3), it is calculated as non-electrical energy, E_{other} in column 13 normally with the domestic electricity:

$$E_{other} = s \cdot V_{norm} \cdot f_{use} \cdot h \cdot G \cdot f_{other} \cdot (1 + \nu_{additional}) \cdot e_{sys} \cdot (1 - f_{solar})$$

For the calculation of the non-electrical primary energy demand, the following data are given in the table header:

- Marginal performance ratio e_{Sys} for DHW. This is needed for the consideration of the DHW demand of washing machines and dishwashers. Taken from the employed systems in the **PE Value** worksheet.
- Marginal performance ratio e_{Sys} for the heating system. This is needed to consider the heating demand for water evaporation due to clothes drying within

the thermal envelope. Taken from the employed systems in the **PE Value** worksheet.

- Primary Energy Factors of the energy carrier for space heating or DHW system. Taken from the employed systems in the **PE Value** worksheet.

If an input is not provided then a value of 1 is used as the marginal performance ratio. This means that DHW and space heating are assumed to be provided directly by electricity.

f_{other}	column 8a:	$1 - f_{el}$: The portion of the energy that is not provided by electricity (also: Heat from DHW and space heating systems by electric heat pumps or flow-type electric hot water heaters).
$\nu_{additional}$	column 10:	Relative additional useful energy demand due to substitution by non-electrical energy. The value may be negative.
e_{sys}	column 11:	Marginal performance ratio for the useful energy produced from the used final energy. See the **PE Value** worksheet.
f_{solar}	column 12:	Solar thermal contribution (with reference to final energy).

The primary energy demand for each service, $E_{primary}$ (column 14) and the specific demand for primary energy are calculated using

$$e_{Primary} = \frac{E_{el} \cdot p_{el} + E_{other} \cdot p_{other}}{A_{TFA}}$$

p_{el}, p_{other}: **primary energy factor (primary energy used per unit of final energy, in accordance with**

[PHI 1998/7], [Gemis]):

p_{el} = 2.6 kWh/kWh

$p_{natural\ gas}$ = 1.1 kWh/kWh

$p_{fuel\ oil}$ = 1.1 kWh/kWh

The specific primary energy demand for household electricity, which comprises all energy services excluding DHW and space heating, is calculated from:

$$e_{Primary} = \sum_{Service,\ i} e_{Primary,i}$$

$$e_{Primary} = e_{el} \cdot p_{el} + \sum_{Energy\ source,j} e_{Energy\ source,j} \cdot p_{other,j}$$

26.3 Explanations for Energy Services

The following frequencies and utilization factors correspond to standard values.

26.3.1 Dishwashers

Select either "Cold Water Connection" or "DHW Connection" from the drop-down menu.

s	column 1:	Indicates if a dishwasher is planned for the project. 1 = Yes, 0 = No. For multi-unit residences, $0 \leq s \leq 1$. See above for a full description.
	column 2:	Location within the thermal envelope: 1 = Yes; 0 = No.
V_{norm}	column 3:	Insert the standard electricity consumption measured in kWh per use from manufacturer's specifications, converted to a standard dishwasher load of 12 place settings (German standard)[4].
f_{use}	column 4:	Utilization factor for normal consumption. Standard = 1.
h	column 5:	Standard: A pre-assigned value of 65 dishwashing cycles per person and per annum.
G	column 6:	Number of occupants.
f_{el}	column 8:	Standard dishwashers: 100 %. Dishwashers with hot water connection: 50 % (f_{other} = 100 % - f_{el}).
$\nu_{additional}$	column 10:	Reference value with DHW connection: 0.3 (All rinse cycles are warm!)
e_{sys}	column 11:	Marginal performance ratio for DHW preparation for the wash and rinse cycles in column 14, row 3.
f_{solar}	column 12:	Portion of water heated using solar thermal energy.

[4] The Energy Star® standard dishwasher load is defined as 8 place settings + 6 serving pieces. Source: http://www.energystar.gov, "Dishwashers Key Product Criteria".

26.3.2 Washing Machines

Select either "Cold Water Connection" or "DHW Connection" from the drop-down menu.

S	column 1:	Indicates if a washing machine is planned for the project. 1 = Yes, 0 = No. For multi-unit residences, $0 \leq s \leq 1$. see above for a full description.
	column 2:	Location within the thermal envelope: 1 = Yes, 0 = No.
V_{norm}	column 3:	Insert the normal electricity consumption measured in kWh per use from manufacturer's specifications, converted to a standard 5 kg wash load.
f_{use}	column 4:	Generally 1. If the manufacturer's specification refers to hot wash according to older standards: 0.65.
H	column 5:	Preassigned value: 57 clothes washing cycles per person and per annum.
G	column 6:	Number of occupants.
f_{el}	column 8:	Normal washing machines: 100 %. For washing machines with a hot water connection: 55 % (Good hot water regulation is a prerequisite!) f_{other} = 100 % - f_{el}
$\nu_{additional}$	column 10:	Reference value with DHW connection: 0.05.
e_{sys}	column 11:	Wash and rinse cycles: Marginal performance ratio for DHW preparation (column 14, row 3).
f_{solar}	column 12:	Portion of water heated using solar thermal energy.

26.3.3 Clothes Drying

Select the type of clothes dryer from the drop-down menu.

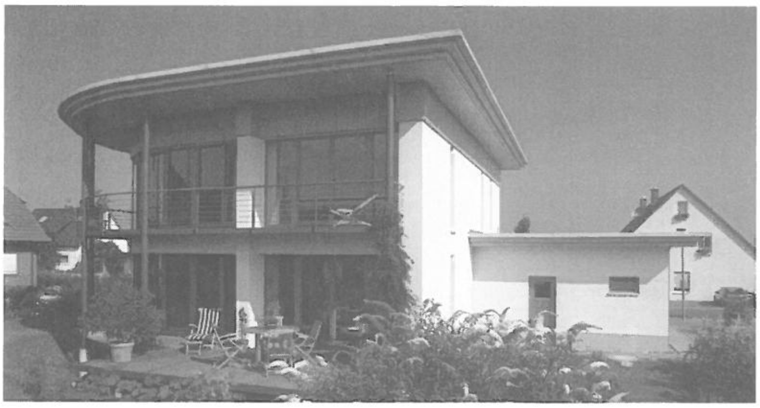
s	column 1:	1 (preassigned)
s_1	column 2:	Location within the thermal envelope: 1 = Yes, 0 = No. Multi-unit residences, $0 \leq s_1 \leq 1$. See above for a full description.
V_{norm}	column 3:	Insert the standard electricity consumption measured in kWh per load from manufacturer's specifications for a standard 5 kg wash. The electricity demand is recorded in the upper cell. For gas-powered clothes dryers, enter the natural gas demand in the lower cell; give the auxiliary electricity load in the upper cell.
Residual Dampness:		From the product specifications of the washing machine: 70 % with a spin cycle at 800-1000 rpm 60 % with a spin cycle at 1000-1100 rpm 50 % with a spin cycle at 1100-1400 rpm.
f_{use}	column 4:	Calculated from the residual dampness according to: (residual dampness + 0.1) / 0.8.
h	column 5:	Preassigned: 57 per person and per annum.
G	column 6:	Number of occupants.
f_{el}	column 8:	When using a clothesline for drying, 0 %; for gas-powered clothes dryers, the portion of the auxiliary energy referred to the total final energy demand; for drying closets, electric exhaust air or condensation clothes dryers, use f_{Other} = 100 % - f_{el}.
$v_{additional}$	column 10:	Additional demand: 0.
e_{sys}	column 11:	Performance ratio: 1.

26.3.4 Clothes Drying: Evaporative Energy Demand

S	column 1:	1, if space heat is required for the drying process. (Exception: condenser dryer. The drying process takes place in the appliance independent from indoor air.) For multi-unit residences, use $0 \leq s \leq 1$. See above.
	column 2:	Location within the thermal envelope: 1 = Yes, 0 = No.
V_{norm}	column 3:	Evaporation enthalpy of 5 kg water: 3.13 kWh/drying cycle.
f_{use}	column 4:	Residual dampness (from the "Residual Dampness" cell).
h	column 5:	Standard: 1.1 per person per week (57 per person per year).
G	column 6:	Number of occupants.
f_{other}	column 8a:	Standard in the Verification process: 1.
$\nu_{additional}$	column 10:	Clothes drying using exhaust air: Reduced unused heat demand of the air-to-air heat exchanger (for higher efficiency counterflow heat exchangers: approx. -0.1).
e_{sys}	column 11:	Marginal performance ratio for space heat provision.
f_{solar}	column 12:	Fraction of the year outside the heating period (standard for Passive Houses approx. 0.6).

26.3.5 Refrigerating and Freezing

S	column 1:	Number of appliances. (Doubling equipment within Passive Houses should be avoided. A refrigerator-freezer combination can be used instead of using a separate refrigerator and freezer). For multi-unit housing, use the number of appliances per number of dwelling units.
	column 2:	Location within the thermal envelope: 1 = Yes, 0 = No.
V_{norm}	column 3:	The standard energy consumption from manufacturer's specifications measured in kWh per day.
f_{use}	column 4:	New, efficient appliances within the thermal envelope = 1. Freezers and refrigerator-freezer combinations in unheated basements: 0.9. Refrigerators in unheated basements: 0.7.
H	column 5:	365 days per year.
G	column 6:	Number of dwelling units.
f_{el}	column 8:	1



Detached house in Ottbergen, Germany
Photo: C. Grobe

26.3.6 Cooking

Select the type of cooking appliance from the drop-down menu.

S	column 1:	1
	column 2:	1 (given)
V_{norm}	column 3:	Demand for standard application. Here: Energy needed for boiling 1.5 l of water. Electric Range / Gas Range: 0.25 kWh Quartz Halogen Ceramic Cooktop: 0.20 – 0.22 kWh Induction Ceramic Cooktop: 0.19 – 0.20 kWh
f_{use}	column 4:	1
H	column 5:	Standard: 500 per person and annum.
G	column 6:	Number of occupants.
f_{el}	column 8:	Electric Range: 1; Gas Range: 0
$v_{additional}$	column 10:	0
e_{sys}	column 11:	1

26.3.7 Lighting

s	column 1:	1
	column 2:	1 (given)

Percentage CFLs: Enter the percentage of the total lighting capacity provided by compact fluorescent light bulbs and energy-conserving light fixtures.

V_{norm}	column 3:	Light bulb performance under normal conditions, 720 Lumen, averaged from the portion of the compact fluorescent light bulbs.
f_{use}	column 4:	1
h	column 5:	Standard: 8 hours per person and day. The value in the table is for 1000 hours per person and year (kh/(P · a).
G	column 6:	Number of occupants.
f_{el}	column 8:	1

26.3.8 Consumer Electronics and Small Appliances

s	column 1:	1
V_{norm}	column 3:	Electronics: Typical television power consumption: 80 W. Small appliances: 50 kWh per person and year.
f_{use}	column 4:	1
h	column 5:	Electronic Standard = 1.5 hours per person and day. The value in the table is for 1,000 hours per person and year (kh/(P · a).
G	column 6:	Enter the number of occupants.
f_{el}	column 8:	1

26.3.9 Auxiliary Electricity

The auxiliary electricity demand is determined in the **Aux Electricity** worksheet. Only the total demand is carried into this worksheet.

26.3.10 Other

In these three rows other devices that consume electrical energy, especially shared electricity equipment that cannot be added to the **Aux Electricity** worksheet (for example, elevators), can be entered. The annual electrical energy demand must be entered under "Norm Demand" in column 3.

26.3.11 List of Appliances

It is necessary to select electrical appliances with the highest energy efficiencies available on the market in order to achieve the lowest possible electrical energy demand (more information about energy efficient household appliances is available from various websites, e.g. the German site www.spargeraete.de. The listed specific energy demand value can be used as a guideline for energy efficiency of the device).

The energy consumption values for all appliances can be found in the product specifications. The manufacturer's specifications must be converted to standard values for 12 place settings for dishwashers, and for wash load sizes of 5 kg for washing machines and clothes dryers.

The listed specific energy demand values are standards for planning the electricity demand during the Passive House verification procedure. It is important to choose appliances so that the overall requirement can be met.

Passive House Planning

ELECTRICITY DEMAND

Building: End-of-Terrace Passive House Kranichstein

# Households	1	HH
Persons	4.5	P
Living Area	156	m²
Annual Heat Demand	14	kWh/(m²a)

Solar Fraction of DHW Wash&Dish	22%
Marginal Performance Ratio DHW	105%
Marginal Performance Ratio Heating	105%

Prim. Energy Factors:			
	Electricity	2.7	kWh/kWh
	Natural Gas	1.1	kWh/kWh
Energy Carrier for Space Heating/DHW:		1.1	1.1

Column Nr.	1	2	3		4	5	6	7	8	8a	9	10	11	12	13	14
Application	Used ? (1/0)	Within the Thermal Envelope? (1/0)	Norm Demand		Utilization Factor	Frequency	Reference Quantity	Useful Energy (kWh/a)	Electric Fraction	Non-Electric Fraction	Electricity Demand (kWh/a)	Additional Demand	Marginal Performance Ratio	Solar Fraction	Non-Electric Demand (kWh/a)	Primary Energy-Demand (kWh/a)
Dishwashing	1	1	1.10 kWh/Use		1.00	65 /(P*a)	4.5 P	319	50%		159					430
DHW Connection										50%		0.30	1.05	0.22	171	188
Clothes Washing	1	1	0.95 kWh/Use		1.00	57 /(P*a)	4.5 P	241	55%		133					358
DHW Connection										45%		0.05	1.05	0.22	94	104
Clothes Drying with:	1	0	0.00 kWh/Use	Residual dampness 0.60	0.88	57 /(P*a)	4.5 P	0	0%		0					0
Clothesline								0		0%			1.00		0	0
Energy Consumed by Evaporation	1	0	0.00 kWh/Use		0.60	57 /(P*a)	4.5 P	0		100%		0.00	1.05	0.65	0	0
Refrigerating	1	1	0.28 kWh/d		1.00	365 d/a	1 HH	102	100%		102					276
Freezing	1	0	0.55 kWh/d		0.90	365 d/a	1 HH	181	100%		181					488
or Combined Unit	0	1	0.70 kWh/d		1.00	365 d/a	1 HH	0	100%		0					0
Cooking with:	1	1	0.25 kWh/Use		1.00	500 /(P*a)	4.5 P	557	0%		0					0
Gas										100%					557	613
Lighting	1	1	21 W	Percentage CFLs 80%	1.00	2.90 kh/(P*a)	4.5 P	269	100%		269					726
Consumer Electroni	1	1	80 W		1.00	0.55 kh/(P*a)	4.5 P	196	100%		196					530
Small Appliances, e	1	1	50 kWh		1.00	1.00 /(P*a)	4.5 P	223	100%		223					602
Total Aux. Electricity								547			547					1476
Other:																
								0			0					0
								0			0					0
								0			0					0
Total								2634 kWh			1809 kWh		DHW Non-Electric - Wash&Dish 321 kWh		822	5790
Specific Demand											11.6 kWh/(m²a)		Non-Renewable Non-Electric DHW Wash&Dish 1.6 kWh/(m²a)		5.3	37.1
Recommended Maximum Value											18					50

27 "Electricity Non-Dom" Worksheet: Calculation of the Electricity Demand for Non-Residential Buildings

With the **Electricity Non-Dom** worksheet, it is possible to balance the electricity demand for lighting, electronic devices (computers, fax machines etc.), and kitchens in non-residential buildings. Additional energy needs such as auxiliary electricity for possible direct electric domestic hot water supply are projected in the **Aux Electricity** and **PE Value** worksheets. In order to use the **Electricity Non-Dom** worksheet for calculations, the building type "Non-Residential" must be selected in the **Verification** worksheet.

27.1 Methods for Calculating the Electricity Demand of Non-Residential Buildings

In the first (top) section of the worksheet, the electricity demand for lighting can be determined. For comparable uses (e.g. individual offices), the calculation can be combined in one row. First, a room type must be selected. The standard utilization patterns are defined in the **Use Non-Dom** worksheet; additional profiles can also be created in this worksheet (see Chapter 36). Once the selection of the room type has been made, the room's required nominal lighting intensity and the utilization period automatically appear.

For a given utilization area, the orientation and geometry of a typical room must be entered. The room should be representative of the project. For example, all the south-facing single office rooms can be combined. The façade shading, sorted according to main sky directions, is automatically copied from the **Windows** worksheet. With the room geometry, windowsill height, window width, and shading, the degree of daylighting is evaluated in the column "Daylight Utilization." Additionally, the full load period of the lighting is calculated. The standard power rating density [W/m^2] of the installed lighting is calculated from the nominal lighting intensity. These values are the limits set out in [LEE]; the power rating of the lighting actually installed should remain below these values. If some values are already available from the lighting design, they should be entered in the column "Own Data: Power Rating of Installed Lighting." In the columns "Lighting Control" and "Motion Detector", a possible daylight-dependent lighting control can be accounted for. The following options for such control are available:

- Manual: manual control by the user
- Autarkic (without information from other systems), continuous operation (with sufficient daylighting, the artificial lighting is set to the lowest level)

- Autarkic; non-continuous operation (with sufficient daylighting, the artificial lighting is turned off)
- Bus system (control of artificial lighting according to daylighting with additional information from other systems)

Conscious control of the artificial lighting by the user can reduce the number of full power operating hours considerably, even with manual control.

The full load lighting hours are calculated in accordance to [DIN V 18599-4]. The power rating density of installed lighting is calculated according to the limit values in [LEE]. To estimate the daylight utilization in the room, an approximation algorithm for the daylighting quotient is used (see [de Boer]).

Further below in the worksheet, the electricity demand for electronic devices can be projected. By choosing the room type, a specific utilization profile (number of utilization hours during the year/period of absence) is defined. The corresponding utilization patterns are defined in the **Use Non-Dom** worksheet (refer to Chapter 36).

The power consumption of the electronic devices should match the manufacturer's specifications. The default values indicate reasonable figures; for the monitor, a TFT monitor is assumed. Information about energy efficient office devices can be found at www.eu-energystar.org/. It is assumed that printers and photocopiers are only used during the utilization period; in other words, they will be turned off in the evening. Continuous operation was assumed for servers.

In the lowest section of the worksheet, the electricity demand for kitchen devices can be calculated. By choosing the room type, the number of utilization days is defined. To determine the electricity demand for cooking and washing, the number of meals per day must be entered. These services can be completely or partly provided without using electricity (e.g. cooking with gas or connecting the dishwasher to the DWH system). The resulting final and primary energy for these services is fully calculated in the **Electricity Non-Dom** worksheet. The projection of standard consumption for cooking and washing corresponds to the assumptions in Chapter 26 (Electricity). The standard consumption values for cooling and any other energy services must correspond to those provided by the respective equipment manufacturers. The values should be entered as electricity demand per utilization day.

Passive House Planning

ELECTRICITY DEMAND Non-domestic Use

Building: End-of-Terrace Passive House Kranichstein

Treated Floor Area A_{TFA}:	156.0	m²
Auxiliary Electricity Demand:	546.2	kWh/a
Primary Energy Factors:		
Electricity:	2.7	kWh/kWh
Gas:	1.1	kWh/kWh
Energy Carrier for DHW:	1.1	kWh/kWh
Solar Fraction of DHW	54%	
Marginal Performance Ratio DHW:		

Calculation in Electricity worksheet!

Window Properties (from Windows worksheet):

	Shading	Dirt Factor	Non-Perpendicular Radiation	Glazing Fraction
North	0.89	0.95	0.85	0.64
East	0.75			0.00
South	0.84			0.65
West	0.82			0.60

Lighting / Non-Domestic	Fraction of Treated Floor Area	Room Category	Room Category	Nominal Illuminance Level	Facade with Windows: Deviation from North	Facade with Windows: Orientation	Facade with Windows: Light Transmission Glazing	Room Geometry: Input of a Typical Room or Room by Room: Room Depth	Room Width	Room Height	Lintel Height	Window Width	Input Warning	Daylight Utilisation	User Data: Installed Lighting Power	Installed Lighting Power (Standard)	Lighting Control	Motion Detector with/without (1/0)	Lighting Control		Utilisation Hours per Year [h/a]	User Determined: Lighting Full Load Hours	Full Load Hours of Lighting	Electricity Demand (kWh/a)	Spec. Electricity Demand (kWh/(m²a))	Primary Energy Demand (kWh/a)
Room / Zone				Lux	Degrees		-	m	m	m	m	m			W/m²	W/m²						h/a		kWh/a		
Offices	80%	22	Group Office	500	0	North	69%	5.0	5.0	2.8	2.5	4.5		medium		15.0	1	0	manual	Without Motion	2750		1302.0	2.44E+03	19.5	6580.8
Circulation Areas	20%	38	Circulation Area	100	270	West	69%	3.0	10.0	2.8	2.5	4.5		medium		4.6	1	0	manual	Without Motion	2750		1440.0	2.07E+02	6.6	558.0
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	
					90	East	69%									0.0	1	0	manual	Without Motion					0.0	

Office Equipment	Room Category	Room Category	In the thermal envelope? (1/0)	Existing/Planned? (1/0)	Quantity	Power Rating (W)	Utilisation Hours per Year (h/a)	relative absenteeism	Duration of Utilisation in Energy Saving Mode (h/a)	Useful Energy (kWh/a)	Electricity Demand (kWh/a)	Primary Energy Demand (kWh/a)
PC 1	22	Group Office	1	1	6	100	1925	0.3		809	808.5	2183
PC in Energy Saving Mode			1		6	1.5	1925	0.3		5	5.2	14
Monitor 1	22	Group Office	1	1	6	28	1925	0.3		226	226.4	611
Monitor in Energy Saving Mode			1		6	2.0	1925	0.3		7	6.9	19
PC 2	0		1	0	0	100	0	0		0	0.0	0
PC in Energy Saving Mode			1		0	1.5	0	0		0	0.0	0
Monitor 2	0		1	0	0	28	0	0		0	0.0	0
Monitor in Energy Saving Mode			1		0	2.0	0	0		0	0.0	0
Copier	22	Group Office	1	0	1	400	2750		2475	0	0.0	0
Copier in Energy Saving Mode			1		1	70	2475			0	0.0	0
Printer	22	Group Office	1	1	2	300	2750		2200	330	330.0	891
Printer in Energy Saving Mode			1		2	8	2200			35	35.2	95
Server	22	Group Office	1	1	1	100	2750			275	275.0	743
Server in Energy Saving Mode			1		1	50.0	8760		2750	301	300.5	811
Telephone System			1	1	1	200	8760			1752	1752.0	4730
Hand Dryer (WC)			1	1	6	2000	125			1500	1500.0	4050
										0	0.0	0
										0	0.0	0
										0	0.0	0
										0	0.0	0

Kitchen / Aux. Electricity	Room Category	Predominant Utilisation Pattern of Building	In the thermal envelope? (1/0)	Existing/Planned? (1/0)	Utilisation Days per Year (d/a)	Number of Meals per Utilisation Day	Norm Consumption	Useful Energy (kWh/a)	Non-Electric Fraction	Electric Fraction	Additional Demand	Marginal Performance Ratio	Solar Fraction	Other Primary Energy Demand (kWh/a)	Electricity Demand (kWh/a)	Primary Energy Demand (kWh/a)
Cooking (Gas 2)	0		1	1	0	4	0.25 kWh/Meal	0	100%	0%				0	0.0	0
																0
Dishwashing (Warmwasseranschluß 2)			1	1	0	4	0.10 kWh/Cover	0	45%	55%	0.30	1.20	0.54	0	0.0	0
																0
Refrigerating			1	1	365		0.38 kWh/d	140		100%					140.0	378
Coffee machine			1	1	200		0.25	50		100%					50.0	135
								0		100%					0.0	0
								0		100%					0.0	0
								0		100%					0.0	0
								0		100%					0.0	0
								0		100%					0.0	0
								0		100%					0.0	0
								0		100%					0.0	0
Total Auxiliary Electricity								546							546.2	1475

	Useful Energy	Hot Water Non-Electric Dishwashing	Other Primary Energy Demand	Electricity Demand	Primary Energy Demand
Total	8620 kWh	0	0	8620 kWh/a	23274 kWh/a
Specific Demand		0.0	0.0	55 kWh/(m²a)	149 kWh/(m²a)

28 "Aux Electricity" Worksheet: Calculating the Auxiliary Electricity Demand

The term “auxiliary electricity” describes all electrical consumption that is necessary to run or control the building’s mechanical systems: heating, ventilation, solar thermal systems and DHW systems. The **Aux Electricity** worksheet is organized according to three categories of building services installations: ventilation, space heating, and DHW. The following system components are included in this sheet:

- Fan and ventilation system controls
- Defrosting of the heat exchanger (HX)
- Radiant heating system circulation pumps
- Auxiliary electricity heating boiler
- Circulation pump - DHW
- Storage load pump - DHW
- DHW boiler - auxiliary electricity
- Solar thermal auxiliary electricity
- Misc. auxiliary electricity

Standard values are assigned to the electrical components. User defined data may be entered and is then used in the calculation. In general, lower auxiliary energy consumption results from using product specific data, e.g., from appliance certifications for components suitable for Passive Houses.

An additional field is provided in the worksheet header to specify a threshold temperature for a frost protection device in the ventilation outdoor air duct. If a subsoil heat exchanger is not planned for the project it is possible that frost will form on the plate heat exchanger on cold winter days, due to insufficient heat in the exhaust air. Some manufacturers provide an electric defroster in which case the electrical demand is calculated in the **Aux Electricity** worksheet.

The minimum allowed outdoor air temperature which activates the defrost function should be utilized. This temperature does not have to be 0 °C. Depending upon the ventilation unit, the heat in the exhaust air can generally provide sufficient frost protection up to -2 °C or beyond.

28.1 Ventilation System

28.1.1 Ventilation in Summer / Winter

Column 1: With heat recovery generally enter 1, because a high efficiency ventilation system must be operated during the entire heating period in Passive Houses. If the building uses natural ventilation during the summer, enter 0 in the second row. If mechanical ventilation is used outside the heating period, enter 1.

Column 2: Determines whether the considered appliance is located within the thermal envelope: 1 = Yes, 0 = No. Any usable portion of waste heat from the fan is already considered in η_{HR}, therefore it is not considered as an internal heat source on this worksheet.

Column 3: The electricity demand given in the certificate for the fan per cubic meter of circulated air. Standard values: 0.45 Wh/m^3 with heat recovery (quality requirement for Passive Houses), 0.25 Wh/m^3 without heat recovery.

Column 4: Air Exchange Rate (automatically transferred from the **Ventilation** worksheet).

Column 5: Period of operation.

Column 6: Air Volume (automatically transferred from the **Annual Heat Demand** worksheet).

Column 8: Availability: 0, because the available waste heat from the fan is already considered in the heat recovery efficiency.

28.1.2 Defrosting the Heat Exchanger

Column 1: 1, if an electric defrost function exists (given by the manufacturer).

Column 2: Always 0 (the heat is almost completely lost to the surroundings)

Column 3: Calculated electrical power of the frost protector.

Column 4: 1

Column 5: Period of operation: mainly dependent upon the minimal temperature requirement of the HRV

Column 6: 1, or the number of ventilation systems in multi-family buildings.

Column 8: Availability: 1.

28.2 Heating System

28.2.1 Circulation Pumps for Hydronic Heating Systems

(e.g. radiators or underfloor heating)

Column 1: Existing or planned circulation pump: 1 = Yes, 0 = No.

Column 2: Located within the thermal envelope: 1 = Yes, 0 = No.

Column 3: Electrical power (standard value or user-defined input)

Column 4: Pump regulated (1) or unregulated (0)

Column 5: Period of operation. Standard: 5.4 kh/a (24 h daily in the heating period)

Column 6: 1 (or the number of circulation pumps).

Column 8: Availability: 1.

28.2.2 Auxiliary Energy for the Space Heating Boiler

Column 1: 1 is automatically inserted if space heating is supplied by a boiler, i.e. if a portion of the annual heat demand is provided by a boiler according to the **Boiler** worksheet.

Column 2: Located within the thermal envelope: 1 = Yes, 0 = No.

Column 3: Electrical power at 30 % load (standard value or user-defined input).

Column 4: 1

Column 5: Period of operation.

Column 6: 1 (or the number of boilers)

Column 8: Availability: 1

28.3 DHW System

28.3.1 DHW Circulation Pump

This section describes hot water recirculation systems used to provide instant hot water at the plumbing fixture. Note that in the **DHW+Distribution** worksheet there are separate sections for entering recirculation and standard distribution lines.

column 1: 1 is automatically inserted if the length of the circulation pipes in the **DHW + Distribution** worksheet is greater than 0.

column 2: Located within the thermal envelope: 1 = Yes, 0 = No.

column 3: Average electrical power rating of the pump (standard value or user-defined input).

column 4: 1

column 5: Period of operation.

column 6: 1

column 8: Availability: 0.6. Waste heat is only usable during the heating period.

28.3.2 DHW Thermal Storage Pump

column 1: 1, if a thermal storage pump is planned or exists.

column 2: Located within the thermal envelope: 1 = Yes, 0 = No.

column 3: Average electrical power rating of the pump (standard value or user-defined input).

column 4: 1

column 5: The period of operation, depending upon the performance of the heat generator, excluding heat pumps and HRV units with integrated heat pump.

column 6: 1

column 8: Availability: 0.6. Waste heat is only usable during the heating period.

28.3.3 Auxiliary Energy Required for Hot-Water Heating Systems

column 1: 1 is automatically inserted if DHW is supplied by a boiler, i.e. if a portion of the annual DHW demand is provided by a boiler according to the **Boiler** worksheet.

column 2: Located within the thermal envelope: 1 = Yes, 0 = No.

column 3: Electrical power rating with 100 % load (standard value or user-defined input).

column 4: 1

column 5: Period of Operation

column 6: 1, (or number of boilers).

column 8: Availability: 1

28.3.4 Auxiliary Electricity for Solar Thermal Systems

column 1: 1 is automatically inserted if the total solar thermal collector area in the **SolarDHW** worksheet is greater than 0.

column 2: Located within the thermal envelope: 1 = Yes, 0 = No.

column 3: Electrical power rating (standard value or user-defined input).

column 6: 1, or the number of solar thermal pumps for multi-unit residences.

column 8: Availability: 0.6. Waste heat is only usable during the heating period.

28.4 Other Auxiliary Electricity

This row is used for miscellaneous auxiliary electrical demand components. Examples of usage would be, e.g.: condensate pumps of air subsoil heat exchangers, circulation pumps of brine geothermal heat exchangers (regular or with ground probes) or the energy consumption of central building control systems.

Passive House Planning

AUXILIARY ELECTRICITY

Building: End-of-Terrace Passive House Kranichstein

1	Living Area	156	m²
2	Heating Period	225	d
3	Air Volume	390	m³
4	Dwelling Units	1	HH
5	Enclosed Volume	665	m³

Operation Vent. System Winter	5.40	kh/a
Operation Vent. System Summer	3.36	kh/a
Air Change Rate	0.30	h^{-1}
Defrosting HX from	-3.0	°C

Primary Energy Factor - Electricity	2.7	kWh/kWh
Annual Space Heat Demand	14	kWh/(m²a)
Boiler Rated Power	3	kW
DHW System Heat Demand	3967	kWh/a
Design Flow Temperature	55	°C

Column Nr. / Application	1 Used? (1/0)	2 Within the Thermal Envelope? (1/0)	3 Norm Demand	4 Utilization Factor	5 Period of Operation	6 Reference Size	7 Electricity Demand (kWh/a)	8 Available as Interior Heat	9 Used During Time Period (kh/a)	10 Internal Heat Source (W)	11 Primary Energy Demand (kWh/a)
Ventilation System											
Winter Ventilation	1	1	0.40 Wh/m³	0.30 h^{-1}	5.4 kh/a	390 m³	253	considered in heat recovery efficiency			682
Summer Ventilation	0	1	0.40 Wh/m³	0.30 h^{-1}	3.4 kh/a	390 m³	0	no summer contribution to IHG			0
Defroster HX	0	0	304 W	1.00	0.1 kh/a	1	0	1.0	5.40	0	0
Heating System											
Enter the Rated Power of the Pump			21 W	Controlled/Uncontrolled (1/0): 1							
Circulation Pump	1	0	21 W	0.8	5.4 kh/a	1	87	1.0	5.40	0	234
Boiler Electricity Consumption at 30% Load			W								
Aux. Energy - Heat Boiler	1	0	25 W	1.00	2.37 kh/a	1	60	1.0	5.40	0	163
DHW system											
Enter Average Power Consumption of Pump			6 W								
Circulation Pump	1	0	6 W	1.00	4.8 kh/a	1	29	0.6	8.76	0	79
Enter the Rated Power of the Pump			W								
Storage Load Pump DHW	0	0	57 W	1.00	1.3 kh/a	1	0	1.0	5.40	0	0
Boiler Electricity Consumption at 100% Load			W								
DHW Boiler Aux. Energy	1	0	76 W	1.00	0.6 kh/a	1	46	1.0	5.40	0	124
Enter the Rated Power of the Solar DHW Pump			W								
Solar Aux Electricity	1	1	41 W	1.00	1.8 kh/a	1	71	0.6	8.76	5	192
Misc. Aux. Electricity											
Misc. Aux. Electricity	0	0	30 kWh/a	1.00	1.0	1 HH	0	1.0	8.76	0	0
Total							546			5	1475
Specific Demand kWh/(m²a)		Divide by Living Area:					3.5				9.5

29 "PE Value" Worksheet: Calculating the Primary Energy Demand and CO_2 Emissions

The specific primary energy demand is the sum of all primary energy demands for heating, DHW, auxiliary and household electricity, i.e. for all energy consumptions within the building, per unit of TFA. The specific primary energy demand describes the amount of non-renewable primary energy which is necessary for providing the energy carrier. It considers the energy content of the raw materials as well as the losses from distribution, conversion and delivery to the end-user [Loga 1997], [Gemis].

The specific primary energy demand of various heating systems can be calculated in the PHPP 2007, including combinations of different types of systems. The heating system categories are

- Electric space heating and electric DHW boilers
- Heat pumps
- Passive House compact units with electric heat pump
- Natural gas, fuel oil or wood boilers
- District heat
- Other heating systems. For such systems, the COP of the heater must be known in advance. If necessary, the COP value must be assessed using other methods.

The specific demands (primary energy and CO_2) for heating, DHW and auxiliary electricity are calculated along with the respective values for heating, DHW, auxiliary and household electricity.

Combining Different Heating Systems

The user can combine different heating systems by stating the percentage of space heat provided by each system. A cogeneration plant provides e.g. 90 % of the annual heat demand, and 10 % is supplied by a wood stove. The entries in the worksheet would then be 90 % in the “District Heat” section and 10 % in the “Miscellaneous” category.

District Heat			PE Value	CO_2-Emission Factor (CO_2-Equivalent)
Covered Fraction of Space Heat Demand	*(Project)*	0%	kWh/kWh	g/kWh
Covered Fraction of DHW Demand	*(Project)*	0%	0.7	-70
Heat Source	*(District Heat worksheet)*			
Utilisation Factor Heat Generator	*(District Heat worksheet)*	95%		
Heat Demand District Heat (without DHW Wash&Dish)	*(District Heat worksheet)*	0.0	0.0	0.0
Non-Electric Demand, DHW Wash&Dish	*(Electricity worksheet)*	0.0	0.0	0.0
Total District Heat		**0.0**	**0.0**	**0.0**

Other			PE Value	CO_2-Emission Factor (CO_2-Equivalent)
Covered Fraction of Space Heat Demand	*(Project)*	0%	kWh/kWh	g/kWh
Covered Fraction of DHW Demand	*(Project)*	0%	0.2	55
Heat Source	*(Project)*	Wood		
Utilisation Factor Heat Generator	*(Project)*	74%		
Annual Energy Demand, Space Heating		0.0	0.0	0.0
Annual Energy Demand, DHW (without DHW Wash&Dish)		0.0	0.0	0.0
Non-Electric Demand, DHW Wash&Dish	*(Electricity worksheet)*	0.0	0.0	0.0
Non-Electric Demand Cooking (Gas for Cooking)	*(Electricity worksheet)*	3.6	3.9	0.9
Total - Other		**3.6**	**3.9**	**0.9**

If one system covers the total demand, enter 100 % there and 0 % in all other categories. This applies to the DHW system, too.

For compact units with heat pumps, the electrical or non-electrical additional space heat is included in the final energy demand. It is sufficient to enter 100 % in the “Compact Heat Pump Unit” category.

Space Cooling

In the **PE Value** worksheet the energy demand for space cooling with an electric heat pump can be taken into account if applicable. The cell for the relative contribution to meeting the cooling demand has been set beforehand to 100 %, as other active space cooling systems can not be taken into account yet in the PHPP 2007. Also necessary is the annual cooling COP.

For the smaller A/C-units cooled by the outdoor air, up to 12 kW power, that are habitually used in residential buildings, the manufacturer's specifications from the energy efficiency class label can be used to determine the annual cooling COP. Poor units only achieve a performance coefficient of about 2.5. A/C-units of energy efficiency class A achieve values above 3.2 and compact units still go above 3. The corresponding fraction of auxiliary electric energy is already included. Compact units which deliver the warm exhaust air to the outside through a flexible tube that is fixed in the window are absolutely unsuitable for energy efficient space cooling.

Large units, for example water-cooled turbo compressors with over 500 kW power can achieve COPs of more than 6.

29.1 Solar Thermal Collector Systems

When a solar thermal collector system is planned, the details are to be entered in the **SolarDHW** worksheet. The **PE Value** worksheet automatically subtracts the solar thermal energy from the primary energy demand.

29.2 Final Energy Demand

Basically, the following holds for the final energy demand:

$$Q_{final} = e_{distribution} \cdot e_{heat\ production} \cdot Q_{use}$$

Q_{use}: Effectively usable heat, i.e. the sum of the annual heat demand and the hot water demand.

$e_{distribution}$: Performance ratio of the heat distribution system

$e_{heat\ production}$: Performance ratio of the heat generator. It is defined as the amount of final energy, in kWh, that is required to produce 1 kWh of useful heat. For heat pumps, the performance ratio is less than 1 because a portion of the useful energy does not come directly from electricity, but is gained by extracting heat from exhaust air or another heat transfer medium.

The calculation of $e_{heat\ production}$ can differ for each system. A variety of calculation sheets is available for different systems.

- $e_{heat\ production}$ is approximately 100 % for electric resistance space heating and electric DHW boilers. The calculation of the specific energy demand and CO_2 values take place in the **PE Value** worksheet.
- The calculation of the COPs of heat pumps is only possible for compact heat pump units in the PHPP 2007. The calculation of COPs of other heat pumps is planned for a future version.

e_{HP}: Determines the amount of useful heat, in kWh, that is provided by the heat pump from one kWh of electricity. This is determined using a separate calculation or from manufacturer's specifications.

e_{system}: In extremely cold temperatures, the heat pump can no longer extract enough heat from the heat source to meet the useful heat demand. The supplementary heating system must deliver the missing heat. Natural gas and electric space heating systems essentially have lower COPs than a heat pump, which elevates the average annual heating system performance ratio considerably. e_{System} determines how much final energy in kWh is needed to produce one kWh of useful heat with the combination of heat pump and supplementary heating system averaged over one year (in accordance with a separate calculation).

- The **Boiler** Worksheet calculates $e_{heat\ production}$ and the specific energy demand and CO_2 values for various natural gas and oil boilers. The calculation is performed if the value for the fraction of heat provided by the boiler is greater than zero in the **PE Value** worksheet and if the device-specific entries in the **Boiler** worksheet are complete.
- In the **District Heat** worksheet, $e_{district\ heating\ station}$ must be given. It is used to calculate the specific energy demands and CO_2 demands for various district heating systems including cogeneration stations (CHP plants).

29.3 Primary Energy Demand

The primary energy demand is calculated using the formula

$$\mathbf{Q_P = p \cdot Q_{final}}$$

p: Non-renewable primary energy factor of the energy carrier, automatically calculated except for “miscellaneous systems”. A list of the primary energy factors in accordance with [DIN V 4701-10] and [Gemis] (adjusted for European conditions) is found both in the **Data** Worksheet and in Table 12.

Q_{final}: Final energy demand

Table 12: **Non-renewable primary energy factors and CO_2-equivalent emission factors from various energy providers ([DIN V 4701-10], [Gemis]; as of April 2004)**
CHP = Coal Heat Plant
CCP = Coal Cogeneration Plant
CGS = Cogeneration Station, HSS Heat Supply Station
PHC = Power Heat Coupling
*** This value exclusively considers the non-renewable portions.**

Energy Source	Abbreviation	Primary Energy Factor	CO_2-Equivalent Emission Factor
		kWh_{prim} / kWh_{final}	kg / kWh_{final}
Fuels	Oil	1.1	0.31
	Natural Gas	1.1	0.25
	Liquid Gas	1.1	0.27
	Hard Coal	1.1	0.44
	Wood	0.2*)	0.05
Electricity	Electricity Mix	2.6	0.61
	PV-Electricity	0.7	0.25
District Heating	CCP 70 % PHC	0.8	0.24
	CCP 35 % PHC	1.1	0.32
	CHP 0 % PHC	1.5	0.41
Gas Cogeneration Station	CGS 70 % PHC	0.7	-0.07
	CGS 35 % PHC	1.1	0.13
	HSS 0 % PHC	1.5	0.32
Oil Cogeneration Station	CGS 70 % PHC	0.8	0.10
	CGS 35 % PHC	1.1	0.25
	HSS 0 % PHC	1.5	0.41

The energy efficiency of a building, including heat supply, is characterized by the primary energy value q_p. Through this value buildings may be compared to each other independent of the type of energy source.

The following formula is used to calculate the specific demand for primary energy:

$$q_p = Q_p / A_{TFA}$$

Q_p: Primary energy demand

A_{TFA}: Treated floor area

29.4 Requirement

The limiting value of the primary energy demand for Passive Houses is [PHI 1997/1]:

$$q_p \leq 120 \text{ kWh/(m}^2\text{a)}$$

29.5 Carbon Dioxide Emissions

The greenhouse gas emissions can be calculated from the final energy demands of the relevant energy suppliers (CO_2, CH_4, CO, NMVOC, NO_X and N_2O). The equivalent greenhouse gas potential is used as a measure for the global warming effect. The CO_2-equivalent is defined as the global warming potential of each gas converted to equivalent quantities of CO_2 [Gemis]. The specific characteristic CO_2-equivalent emissions value is defined as the sum of the individual values of all the energy sources in accordance with

$$u_{CO2} = \frac{U_{CO2}}{A_{TFA}}$$

where

$$U_{CO2} = x_{CO2} \cdot E_{H+W}$$

u_{CO2}: Specific CO_2-equivalent emissions [kg/(m²a)]

U_{CO2}: Annual CO_2-equivalent emissions [kg/a]

x_{CO2}: CO_2-equivalent emissions factor [kg/kWh$_{Final}$]

The x_{CO2}-values can be found in Table 12.

Passive House Planning

PRIMARY ENERGY VALUE

Building:	End-of-Terrace Passive House Kranichstein	Building Type/Use:	Terraced House/Dwellings	
Location:	Darmstadt Kranichstein	Treated Floor Area A_{TFA}:	156	m²
		Space Heat Demand incl. Distribution	14	kWh/(m²a)
		Useful Cooling Demand:	0	kWh/(m²a)

			Final Energy kWh/(m²a)	Primary Energy kWh/(m²a)	Emissions CO_2-Equivalent kg/(m²a)
Electricity Demand (without Heat Pump)				PE Value	CO_2-Emissions Factor (CO_2-Equivalent)
Covered Fraction of Space Heat Demand		(Project)	0%	kWh/kWh	g/kWh
Covered Fraction of DHW Demand		(Project)	0%	2.7	680
Direct Electric Heating	$Q_{H,de}$		0.0	0.0	0.0
DHW Production, Direct Electric (without Wash&Dish)	$Q_{DHW,de}$	(DHW+Distribution, SolarDHW)	0.0	0.0	0.0
Electric Postheating DHW Wash&Dish		(Electricity, SolarDHW)	0.0	0.0	0.0
Electricity Demand Household Appliances	Q_{EHH}	(Electricity worksheet)	8.1	21.9	5.5
Electricity Demand - Auxiliary Electricity			3.5	9.5	2.4
Total Electricity Demand (without Heat Pump)			**11.6**	**31.3**	**7.9**
Heat Pump				PE Value	CO_2-Emission Factor (CO_2-Equivalent)
Covered Fraction of Space Heat Demand		(Project)	0%	kWh/kWh	g/kWh
Covered Fraction of DHW Demand		(Project)	0%	2.7	680
Energy Carrier - Supplementary Heating			Electricity	2.7	680
Annual Coefficient of Performance - Heat Pump		Separate Calculation	3.20		
Total System Performance Ratio of Heat Generator		Separate Calculation	0.45		
Electricity Demand Heat Pump (without DHW Wash&Dish)	Q_{HP}		0.0	0.0	0.0
Non-Electric Demand, DHW Wash&Dish		(Electricity worksheet)	0.0	0.0	0.0
Total Electricity Demand Heat Pump			**0.0**	**0.0**	**0.0**
Compact Heat Pump Unit				PE Value	CO_2-Emission Factor (CO_2-Equivalent)
Covered Fraction of Space Heat Demand		(Project)	0%	kWh/kWh	g/kWh
Covered Fraction of DHW Demand		(Project)	0%	2.7	680
Energy Carrier - Supplementary Heating			Electricity	2.7	680
COP Heat Pump Heating		(Compact worksheet)	0.0		
COP Heat Pump DHW		(Compact worksheet)	0.0		
Performance Ratio of Heat Generator (Verification)		(Compact worksheet)			
Performance Ratio of Heat Generator (Planning)		(Compact worksheet)			
Electricity Demand Heat Pump (without DHW Wash&Dish)	Q_{HP}	(Compact worksheet)	0.0	0.0	0.0
Non-Electric Demand, DHW Wash&Dish			0.0	0.0	0.0
Total Compact Unit		(Compact worksheet)	**0.0**	**0.0**	**0.0**
Boiler				PE Value	CO_2-Emission Factor (CO_2-Equivalent)
Covered Fraction of Space Heat Demand		(Project)	100%	kWh/kWh	g/kWh
Covered Fraction of DHW Demand		(Project)	100%	1.1	250
Boiler Type		(Boiler worksheet)	Condensing Boiler Gas		
Utilisation Factor Heat Generator		(Boiler worksheet)	94%		
Annual Energy Demand (without DHW Wash&Dish)		(Boiler worksheet)	25.3	27.8	6.3
Non-Electric Demand, DHW Wash&Dish		(Electricity worksheet)	1.7	1.9	0.4
Total Heating Oil/Gas/Wood			**27.0**	**29.7**	**6.8**
District Heat				PE Value	CO_2-Emission Factor (CO_2-Equivalent)
Covered Fraction of Space Heat Demand		(Project)	0%	kWh/kWh	g/kWh
Covered Fraction of DHW Demand		(Project)	0%	0.7	-70
Heat Source		(District Heat worksheet)			
Utilisation Factor Heat Generator		(District Heat worksheet)	95%		
Heat Demand District Heat (without DHW Wash&Dish)		(District Heat worksheet)	0.0	0.0	0.0
Non-Electric Demand, DHW Wash&Dish		(Electricity worksheet)	0.0	0.0	0.0
Total District Heat			**0.0**	**0.0**	**0.0**
Other				PE Value	CO_2-Emission Factor (CO_2-Equivalent)
Covered Fraction of Space Heat Demand		(Project)	0%	kWh/kWh	g/kWh
Covered Fraction of DHW Demand		(Project)	0%	0.2	55
Heat Source		(Project)	Wood		
Utilisation Factor Heat Generator		(Project)	74%		
Annual Energy Demand, Space Heating			0.0	0.0	0.0
Annual Energy Demand, DHW (without DHW Wash&Dish)			0.0	0.0	0.0
Non-Electric Demand, DHW Wash&Dish		(Electricity worksheet)	0.0	0.0	0.0
Non-Electric Demand Cooking (Gas for Cooking)		(Electricity worksheet)	3.6	3.9	0.9
Total - Other			**3.6**	**3.9**	**0.9**
Cooling with Electric Heat Pump				PE Value	CO_2-Emission Factor (CO_2-Equivalent)
				kWh/kWh	g/kWh
Covered Fraction of Cooling Demand		(Project)	100%	2.7	680
Heat Source			Electricity		
Annual Cooling COP			3.3		
Energy Demand Space Cooling			**0.0**	**0.0**	**0.0**

Heating, Cooling, DHW, Auxiliary and Household Electricity		**42.2**	**65.0**	**15.5**
Total PE Value	**65.0**	kWh/(m²a)		
Total Emissions CO_2-Equivalent	**15.5**	kg/(m²a)		(Yes/No)
Primary Energy Requirement		120	kWh/(m²a)	**Yes**

Heating, DHW, Auxiliary Electricity (No Household Applications)		**28.8**	**37.3**	**8.7**
Specific PE Demand - Mechanical System	**37.3**	kWh/(m²a)		
Total Emissions CO_2-Equivalent	**8.7**	kg/(m²a)		

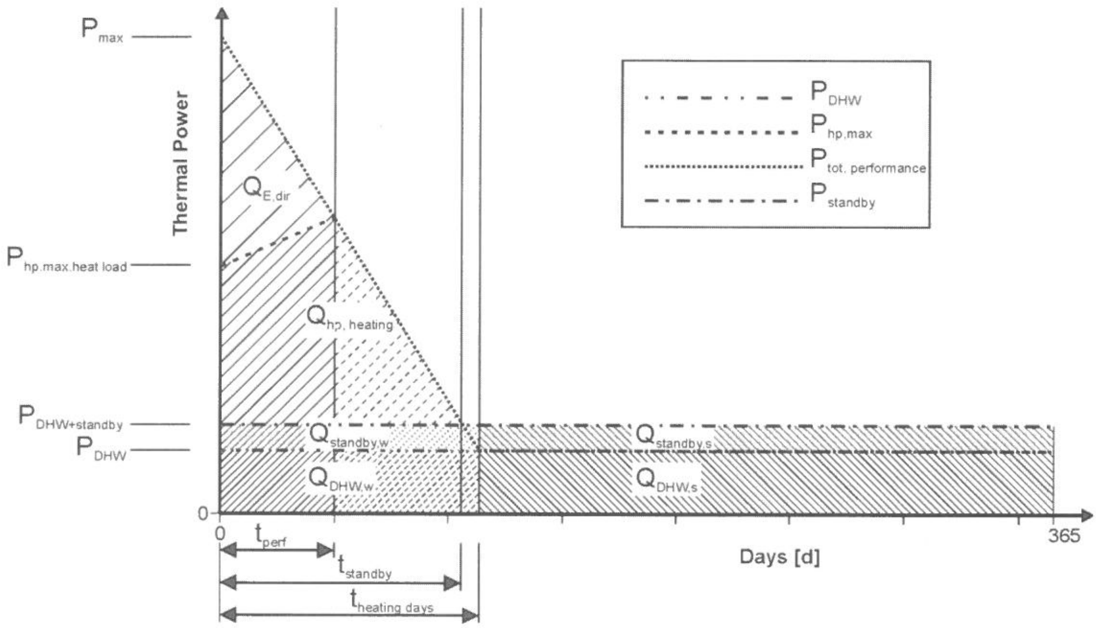
Solar Electricity		kWh/a	PE Value (Savings)	CO_2-Emission Factor
Planned Annual Electricity Generation	Separate Calculation	2600	kWh/kWh	g/kWh
			0.7	250
Specific Demand		**16.7**	**11.7**	**4.2**
PE Value: Energy Conservation by Solar Electricity Generation	**33.3**	kWh/(m²a)		
CO_2-Emissions Avoided Due to Solar Electricity	**7.2**	kg/(m²a)		

30 "Compact" Worksheet: Calculation of Passive House Compact Units

30.1 Fundamentals and Calculation Principles

The coefficient of performance of compact heat pump units for combining heat and DHW supply depends not only on the particular unit used but also on the heating load (heat and DHW demand) of the planned building. It is the responsibility of the HVAC designer to choose a device suitable for the building and its intended use.

In the **Compact** worksheet, the efficiency and the primary energy demand of electrically driven Passive House compact units can be calculated as long as the corresponding parameters from the laboratory tests are available (where testing conditions correspond to the "Component suitable for Passive Houses: compact unit" certification).



P_{DHW}	Average thermal output for DHW
$P_{Standby}$	Average stand-by losses
$P_{HP,max}$	Maximum daily average output for heating and DHW for the design heating load
$Q_{DHW,Winter}$	Amount of heat for DHW in winter
$Q_{DHW,Summer}$	Amount of heat for DHW in summer
$Q_{Standby,Winter}$	Stand-by heat losses in winter
$Q_{Standby,Summer}$	Stand-by heat losses in summer
$Q_{HP,Heating}$	Heat supplied by heat pump
$Q_{E,dir}$	Heat supplied by direct electric heating

Figure 24: Annual load duration curve for Passive House compact units

If the daily average output values for DHW and heating are plotted according to magnitude, a load duration curve similar to that shown in Figure 24 results. The non-linear deviations are generally negligibly small. The areas under the curve are the corresponding heat demands. Compact units are usually dimensioned in such a way that the thermal output of the heat pump in the design case does not fully cover the DHW and heating demands. The peak loads are then covered by direct electric heating (top portion of the triangle in Figure 24, $Q_{E,dir}$). In order to keep the primary energy demand low, the direct-electric portion should be kept between 5 and 10 %.

30.2 Data Input and Calculation

As with the **Ventilation** worksheet, data for the different compact units can be chosen via a drop-down menu in the **Compact** worksheet. Values from certification tests for future PH compact units will always be included in the PHPP-Updates or can be obtained from the certificates themselves posted on the internet. The user's own data can also be entered in the bottom section of the **Compact** worksheet. If needed, other units can be added using "copy and paste" for the appropriate cells (to a maximum of 15 units).

1 Compact Unit, Type 1

Measured Values from Laboratory Test

Ventilation

Effective Heat Recovery Efficiency	$\eta_{HR,eff}$	(Test Stand)	80%	
Electric Efficiency		(Test Stand)	0.43	Wh/m³

(Enter minimum 2, maximum 4 test points, in ascending order of T_{amb})

Heating		Test Point 1	Test Point 2	Test Point 3	Test Point 4	
Ambient Air Temperature	T_{amb}	-5.9	2.0	8.1		°C
Measured Thermal Power Heat Pump Heating	$P_{HP,Heating}$	1.02	1.18	1.49		kW
Measured COP Heating	$COP_{Heating}$	1.52	1.41	1.91		-

(Enter minimum 2, maximum 4 test points, in ascending order of T_{amb}; test point at 20 °C obligatory)

DHW		Test Point 1	Test Point 2	Test Point 3	Test Point 4	
Ambient Air Temperature	T_{amb}	2.0	10.0	20.0		°C
Measured Thermal Power DHW Storage Heating-Up	$P_{DHW\,Heating\text{-}Up}$	1.41	1.76	2.05		kW
Measured Thermal Power DHW Storage Reload	$P_{DHW\,Reload}$	1.17	1.64	1.94		kW
Measured COP DHW Storage Heating-Up	$COP_{DHW\,Heating\text{-}Up}$	1.90	2.30	2.70		-
Measured COP DHW Storage Reload	$COP_{DHW\,Reload}$	1.45	1.97	2.25		-
Standby (Inputs required only if different from storage reload)		Test Point 1	Test Point 2	Test Point 3	Test Point 4	
Ambient Air Temperature	T_{amb}	2.0	10.0	20.0		°C
Measured Thermal Power Heat Pump Standby	$P_{HP\,Standby}$	1.17	1.64	2.05		kW
Measured COP Standby	$COP_{Standby}$	1.45	1.97	2.25		-

Specific Heat Loss Storage incl. Connections	$U \cdot A_{Storage}$	(Test Stand)	2.00	W/K
Average Storage Temperature in Standby Mode	$T_{DHW\,Standby}$	(Test Stand)	35.6	°C
Heat Pump Priority (please check as appropriate)		(Manufacturer. Techn. Data)	DHW Priority: x	Heating Priority:
Volume Flow Rate of Added Exhaust Air (if applicable)	V_{add}	(Test Stand)	150	m³/h

30.2.1 Ventilation

Since the compact unit functions as both a heat and DHW production unit and a ventilation unit, the certified values for the effective thermal and electrical efficiencies (measured with the compressor and pumps turned off, i.e. only control and ventilation electricity is used) should also be entered in the **Compact** worksheet. If a compact unit is used, then the "Compact unit selected in **Compact** worksheet" option in the *Device Selection* drop-down menu in the **Ventilation** worksheet should be selected.

30.2.2 Heating

The COP and thermal power values obtained from the laboratory tests under various outside temperatures can be entered in this worksheet. Up to four test points can be entered, but a minimum of 2 is required. The input should be in ascending order according to outside temperature (ex. test points according to EN 14511: -7 °C, 2 °C, +7 °C). At least one of the test points must be below -3 °C.

30.2.3 Domestic Hot Water

As with the heating, measurement results for up to 4 points can be entered. In order to be able to calculate the summertime operation, the last data point for COP and power should be at 20 °C. This is because outside the heating period, the compact unit essentially operates as an exhaust air heat pump.

Connecting the washing machine and dishwasher to the DHW system usually decreases the primary energy consumption, since the extra hot water demand is mainly covered by the heat pump. However, the extra hot water demand should be considered when dimensioning the unit.

30.2.4 Priority for either Heating or DHW

The thermal powers are calculated from the running time of the individual operational modes (DHW, stand-by, or heating). The priority of the unit is important, since there is a variety of products on the market. For example, if the unit is primarily used for producing hot water, then the heat pump can only be used for space heating when it is not needed for hot water production.

The priority operational mode, either “DHW Priority” or “Space Heating Priority” should be chosen in the **Compact** worksheet.

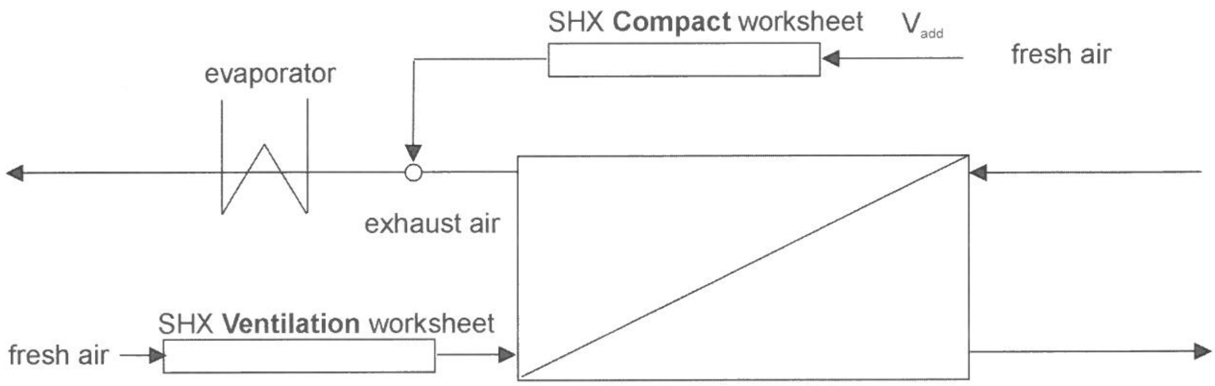
30.2.5 Stand-By

The storage tank losses are calculated in the **Compact** worksheet, which means the storage tank losses in the **DHW + Distribution** worksheet should be set to zero. The heat losses during stand-by operation reduce the heat demand depending on the marginal utilisation factor. The stand-by operation of the compact unit is determined by a separate laboratory measurement. It depends on both the storage tank losses (and other heat emitting components) and the average storage tank temperature during stand-by operation. Therefore, the storage tank's specific thermal losses $U^*A_{Storage}$ and average temperature during stand-by operation $T_{DHW,Standby}$ should be inputted in the **Compact** worksheet. Since the storage tank's average temperature cannot be directly measured, it should be calculated from the measurement results and entered into the sheet. The product of $U^*A_{Storage}$ and the temperature difference between the average storage tank temperature $T_{DHW,Standby}$ and the room in which the tank is located is the heat loss during stand-by operation.

The COP data for stand-by mode normally do not differ from the DHW mode during tank reloading. In this case, the input cells need not be filled in, since the appropriate values will automatically be taken from the “DHW Storage Reload” section. Only if the stand-by operation mode is different, for example caused by special control settings, the data have to be entered in the "Stand-by" section.

30.2.6 Subsoil Heat Exchangers and Frost Protection

The preheating of the air by a subsoil heat exchanger can be used by the compact units in two ways:



1. The outside temperature T_{amb} can be raised via a subsoil heat exchanger. This can serve for example for decreasing the frequency of defrosting operations of the heat pump. The efficiency of this heat exchanger is inputted in the **Ventilation** worksheet. It is assumed that the geothermal heat exchanger also protects the heat exchanger against frost. If no subsoil heat exchanger is present, then it is assumed that a preheater is used. The frost protection temperature is inputted in the **Aux Electricity** worksheet.

2. Some units have a connection for intaking additional fresh air and mixing it with the exhaust air, in order to increase the flow to the evaporator. This can optionally be preheated with an extra subsoil heat exchanger. The efficiency of the process is inputted in the **Compact** worksheet. Since the efficiency of the SHX is not an inherent property of the unit - the SHX is created on the construction site - it is to be entered if applicable in the cell "Efficiency SHX Exhaust Air Mixing".

30.2.7 Treatment of the Compact Unit in other PHPP Worksheets

The following points should be noted when a compact unit is used:

Ventilation worksheet: The option "Compact unit selected in **Compact** worksheet" should be chosen in the unit selection drop-down menu.

Heating Load worksheet: A maximum supply air temperature $\theta_{sup,\ Max}$ of 52°C is set as the default.

> ! Advice
>
> A supply air temperature of 52°C is often not achieved by compact units. In this case, the actual measured value of the unit in the design heating case should be entered

Aux Electricity worksheet: During the COP measurement, the power consumption of an internal circulation pump (if available) is included. Therefore, it is not necessary to input it into the **Aux Electricity** worksheet. Only circulation pumps for external heating circuits are entered in this sheet.

For compact units that are also used in the summer for DHW production, the option "Ventilation in Summer" in the **Aux Electricity** worksheet should be selected.

If no subsoil heat exchanger is included for protecting the internal heat exchanger against frost, then the maximum temperature for frost protection of the preheater must be inputted into the **Aux Electricity** worksheet.

DHW+Distribution worksheet: The losses of the hot water storage tank are already included in the stand-by losses of the compact unit and are, therefore, not considered in this sheet.

SolarDHW worksheet: The heat pump's contribution to the DHW supply in summer is reduced by the solar fraction calculated in this sheet. If the solar fraction is high, then a portion of the DHW supply in winter can also be supplied by the solar collectors. Contributions to the space heating must be entered separately (solar contribution to space heating in the **Compact** worksheet).

Passive House Planning

COMPACT UNIT WITH EXHAUST AIR HEAT PUMP

(Calculation from Values Measured in the Laboratory Test for Unit Certification)

Building:	End-of-Terrace Passive House Kranichstein	Building Type/Use:	Terraced House/Dwellings	
Location:	Darmstadt Kranichstein	Treated Floor Area A_{TFA}:	156	m²

Covered Fraction of Space Heat Demand		(PE Value worksheet)	100%	
Space Heat Demand + Distribution Losses	Q_H+Q_{HL}	(DHW+Distribution)	1410	kWh
Solar Fraction for Space Heat	$\eta_{Solar,H}$	(Separate Calculation)	0%	
Effective Annual Heat Demand	$Q_{H,Wi}=Q_H*(1-\eta_{Solar,H})$		**1410**	kWh
Covered Fraction of DHW Demand		(PE Value worksheet)	100%	
Total Heat Demand of DHW system	Q_{gDHW}	(DHW+Distribution)	3337	kWh
Solar Fraction for DHW	$\eta_{Solar,DHW}$	(SolarDHW worksheet)	54%	
Effective DHW Demand	$Q_{DHW,Wi}=Q_{DHW}*(1-\eta_{Solar,DHW})$		**1526**	kWh

Selection of Compact Unit (Data Inputs from Row 173): Compact Unit, Type 1

Measured Values from Laboratory Test

Ventilation

Effective Heat Recovery Efficiency	η_{eff}	(Test Stand)	80%	
Electric Efficiency		(Test Stand)	0.43	Wh/m³

Heating

		Test Point 1	Test Point 2	Test Point 3	Test Point 4	
Ambient Air Temperature	T_{amb}	-5.9	2.0	20.0		°C
Measured Thermal Power Heat Pump Heating	$P_{HP,Heating}$	1.02	1.18	1.49		kW
Measured COP Heating	$COP_{Heating}$	1.52	1.41	1.91		-

DHW

		Test Point 1	Test Point 2	Test Point 3	Test Point 4	
Ambient Air Temperature	T_{amb}	2.0	10.0	20.0		°C
Measured Thermal Power DHW Storage Heating-Up	$P_{DHW,Heating-Up}$	1.41	1.76	2.05		kW
Measured Thermal Power DHW Storage Reload	$P_{DHW,Reload}$	1.17	1.64	1.94		kW
Measured COP DHW Storage Heating-Up	$COP_{DHW,Heating-Up}$	1.90	2.30	2.70		-
Measured COP DHW Storage Reload	$COP_{DHW,Reload}$	1.45	1.97	2.25		-

Standby (Inputs required only if different from storage reload)

		Test Point 1	Test Point 2	Test Point 3	Test Point 4	
Ambient Air Temperature	T_{amb}	2.0	10.0	20.0		°C
Measured Thermal Power Heat Pump Standby	$P_{HP,Standby}$	1.17	1.64	2.05		kW
Measured COP Standby	$COP_{Standby}$	1.45	1.97	2.25		-

Specific Heat Loss Storage incl. Connections	$U*A_{Storage}$	(Test Stand)	2.00	W/K
Average Storage Temperature in Standby Mode	$T_{DHW,Standby}$	(Test Stand)	35	°C

Heat Pump Priority (please check as appropriate) (Manufacturer, Techn. Data) DHW Priority: x Heating Priority:

	Room Temperature (°C)		20	
	Av. Ambient Temp. Heating P. (°C)		4	
	Av. Ground Temp (°C)		10	
Efficiency SHX Exhaust Air Mixing	$\eta*_{SHX}$		50%	
Heat Recovery Efficiency SHX Exhaust Air Mixing (if applicable)	$\eta_{SHX,add}$	(Design Value)	21%	
Volume Flow Rate of Added Exhaust Air (if applicable)	V_{add}	(Test Stand)	150	m³/h

Heat Supplied by Direct Electricity	$Q_{E,dir}$	188	kWh/a
Space Heat Supplied by HP	$Q_{HP,Heating}$	1167	kWh/a
Winter DHW Supplied by HP	$Q_{HP,DHW,Winter}$	705	kWh/a
Winter Standby Heat Supplied by HP	$Q_{HP,Standby,Winter}$	56	kWh/a
Summer DHW Supplied by HP	$Q_{HP,DHW,Summer}$	2631	kWh/a
Summer Standby Heat Supplied by HP	$Q_{HP,Standby,Summer}$	207	kWh/a

Performance Ratio of Heat Generator, DHW & Space Heating		**85%**	
Annual Coefficient of Performance	COP	1.9	
		kWh/a	kWh/(m²a)
Final Energy Demand Heat Generation	Q_{final}	**2491**	**16.0**
Annual Primary Energy Demand		**6724**	**43.1**
		kg/a	kg/(m²a)
Annual CO_2-Equivalent Emissions		**1694**	**10.9**

31 "Boiler" Worksheet: Calculating the Performance Ratio of Boilers

In this worksheet, the boiler performance ratio for the residual space heating and DHW supply is determined. The calculation of the performance ratio is based upon DIN V 4701-10. The heat supply for space heating and DHW are determined separately using calculation procedures in accordance with this standard.

The already established space heating and DHW demands are automatically transferred into the sheet as input parameters. The energy demands are lowered relative to the portion provided by the solar thermal collector system. The determination of a solar contribution to space heat is not yet possible in the PHPP 2007. If determined by using other methods the solar space heat fraction can be entered in the worksheet in the "solar fraction for space heat" field.

Select the heat source type from the drop-down menu. Possible selections are low-temperature or condensing boilers, using either natural gas or fuel oil sources, or wood-burning boilers. The efficiency of wood pellets and log burning boilers is calculated in a separate part of the worksheet using a different method.

Characteristic data of the heat generator are needed to calculate the performance ratio. If "Y" is entered in the worksheet, the specific data of the burner are used, if "N" is entered, standard values in accordance with DIN V 4701-10 are applied. The default values correspond to minimal demands for low temperature boilers and condensing boilers. More accurate data might be obtainable from the manufacturer.

The given value of 3 kW as design power output of the boiler in the documented example has been determined under the following conditions: A 12 kW condensing boiler supplies four terraced houses; the calculation is performed for one dwelling unit.

If a low temperature or condensing boiler is chosen, then inputs need only be given in the upper cells. Calculations for a wood-pellet or log boiler only require values to be given in the lower portion. Entering the actual efficiency values from the manufacturer will generally result in more favourable performance ratios for the heat generation.

If individual entries are missing, the relevant standard value is used. For DHW heating a year-round operation of 8,760 hours is used. The length of the heating period is determined from the ratio of the space heat demand relative to the average annual heating load.

Passive House Planning

EFFICIENCY OF HEAT GENERATION (GAS, OIL, WOOD)

Building:	End-of-Terrace Passive House Kranichstein	Building Type/Use:	Terraced House/Dwellings	
Location:	Darmstadt Kranichstein	Treated Floor Area A_{TFA}:	156	m²

Covered Fraction of Space Heat Demand		*(PE Value worksheet)*	100%	
Space Heat Demand + Distribution Losses	Q_H+Q_{HS}	*(DHW+Distribution)*	2137	kWh
Solar Fraction for Space Heat	$\eta_{Solar,H}$	*(Separate Calculation)*	0%	
Effective Annual Heat Demand	$Q_{H,Wi}=Q_H*(1-\eta_{Solar,H})$		**2137**	kWh
Space Heat Demand without Distribution Losses	Q_H	*(Annual Heat Demand)*	2152	kWh
Covered Fraction of DHW Demand		*(PE Value worksheet)*	100%	
Total Heat Demand of DHW system	Q_{gDHW}	*(DHW+Distribution)*	3967	kWh
Solar Fraction for DHW	$\eta_{Solar,DHW}$	*(SolarDHW worksheet)*	54%	
Effective DHW Demand	$Q_{DHW,Wi}=Q_{DHW}*(1-\eta_{Solar,DHW})$		**1813**	kWh

Boiler Type		*(Project)*	Condensing Boiler Gas	
Primary Energy Factor		*(Data worksheet)*	1.1	kWh/kWh
CO_2-Emissions Factor (CO_2-Equivalent)			250	g/kWh
Useful Heat Provided	Q_{Use}		3949	kWh/a
Max. Heating Power Required for Heating the Building	P_{BH}	*(Heating Load worksheet)*	1.56	kW
Length of the Heating Period	t_{HP}		2741	h
Length of DHW Heating Period	t_{DHW}		8760	h

Use characteric values entered (check if appropriate)? x

			Project Data		Standard Values		Input field
Design Output	$P_{nominal}$	*(Rating Plate)*	3	kW	15	kW	3
Installation of Boiler (Outdoor: 0, Indoor: 1)			0		0		0
Input Values (Oil and Gas Boiler)			Project Data		Standard Values		Input field
Boiler Efficiency at 30% Load	$\eta_{30\%}$	*(Manufacturer)*	99%		99%		99%
Boiler Efficiency at Nominal Output	$\eta_{100\%}$	*(Manufacturer)*	95%		93%		95%
Standby Heat Loss Boiler at 70 °C	$q_{B,70}$	*(Manufacturer)*	2.0%		2.7%		2.0%
Average Return Temperature Measured at 30% Load	$\vartheta_{30\%}$	*(Manufacturer)*	30	°C	30		
Input Values (Biomass Heat Generator)			Project Data		Standard Values		Input field
Efficiency of Heat Generator in Basic Cycle	η_{GZ}	*(Manufacturer)*			60%		
Efficiency of Heat Generator in Constant Operation	η_{SO}	*(Manufacturer)*			70%		
Average Fraction of Heat Output Released to Heating Circuit	$z_{HC,m}$	*(Manufacturer)*			0.4		
Temperature Difference Betw. Power-On and Power-Off	$\Delta\vartheta$	*(Manufacturer)*		K	30		
For Interior Installations: Area of Mechanical Room	$A_{install}$	*(Project)*		m²	0	m²	
Useful Heat Output per Basic Cycle	$Q_{N,GZ}$	*(Manufacturer)*			4.5		
Average Power Output of the Heat Generator	$Q_{N,m}$	*(Manufacturer)*		kW	3.0		

Utilisation Factor Heat Generator Heating Run	$h_{H,g,K}=f_i*\eta_{K^*}$	**97%**
Utilisation Factor Heat Generator DHW Run	$h_{TW,g,K}=\eta_{100\%}/f_{i,TW}$	**90%**
Utilisation Factor Heat Generator DHW & Heating	$h_{g,K}$	**94%**

		kWh/a	kWh/(m²a)
Final Energy Demand Space Heating	$Q_{Final,HE}=Q_{H,wi}*e_{H,g,K}$	**2198**	
Final Energy Demand DHW	$Q_{Final,DHW}=Q_{WW,wi}*e_{TW,g,K}$	**2016**	
Total Final Energy Demand	$Q_{Final}=Q_{Final,DHW}+Q_{Final,HE}$	**4214**	**27.0**
Annual Primary Energy Demand		**4636**	**29.7**
		kg/a	kg/(m²a)
Annual CO_2-Equivalent Emissions		**1054**	**6.8**

32 "District Heating" Worksheet: Calculating the Performance Ratio of District Heat Transfer Stations

The determined annual heat demand and hot water demand are the entry parameters of this worksheet. In the current version of the PHPP, it is not possible to determine the fraction of space heat provided by a solar thermal system. The reduction from the solar thermal collector system can be entered, though, if it is determined using other means.

Select one of the following types of systems from the drop-down menu:

- hard coal burning district heating facility
- natural gas cogeneration plant
- oil cogeneration plant

It is also possible to include the fraction of cogeneration (combined heat and power, CHP) provided by each system. 35 % CHP means for example, that 35 % of the heat produced by a heat generator is covered by cogeneration (CHP).

The following holds for the performance ratios of heat transfer stations:

Table 13: Heat Transfer Station Performance Ratios

		Space Heating	Hot Water Heating Period	Hot Water Summer
Compact Enclosed Transfer Station		102 %	100 %	111 %
Individual System with Single Pipes	Well-Insulated	105 %	100 %	118 %
	Moderate Insulation	111 %	100 %	125 %

An average value can be used for combined systems of space heating and hot water.

For some cogeneration (CHP) plants, negative CO_2 emissions may be determined. Negative CO_2 emissions occur if the electricity produced by cogeneration plants replaces that generated by conventional coal power plants. The CO_2 reductions by transferring electricity production from coal to cogeneration are greater than the CO_2 emissions produced by the coal power plant alone. The total balance results in negative emissions.

Passive House Planning

EFFICIENCY OF DISTRICT HEATING STATIONS

Building:	End-of-Terrace Passive House Kranichstein	Building Type/Use:	Terraced House/Dwellings	
Location:	Darmstadt Kranichstein	Treated Floor Area A_{TFA}:	156	m²

Covered Fraction of Space Heat Demand		*(PE Value worksheet)*	0%	
Annual Heat Demand kWh/a	Q_H	*(DHW+Distribution)*	2137	kWh
Solar Fraction for Space Heat	$\eta_{Solar, H}$	*(Separate Calculation)*		
Effective Annual Heat Demand	$Q_{H,Wi}=Q_H*(1-\eta_{Solar, H})$		0	kWh
Covered Fraction of DHW Demand		*(PE Value worksheet)*	0%	
DHW Demand	Q_{DHW}	*(DHW+Distribution)*	3967	kWh
Solar Fraction for DHW	$\eta_{Solar, DHW}$	*(SolarDHW worksheet)*	54%	
Effective DHW Demand	$Q_{DHW,Wi}=Q_{DHW}*(1-\eta_{Solar, DHW})$		0	kWh
Heat Source			Gas CGS 70% PHC	
Primary Energy Factor		*(Data worksheet)*	0.7	kWh/kWh
CO_2-Emissions factor (CO_2-Equivalent)		*(Data worksheet)*	-70	g/kWh
Utilisation Factor Heat Transfer Station	$\eta_{a,HX}$		95%	

		kWh/a	kWh/(m²a)
Final Energy Demand Heat Generation	$Q_{final} = Q_{Use} * e_{a,DH}$	0	0.0
Annual Primary Energy Demand		0	0.0
		kg/a	kg/(m²a)
Annual CO_2-Equivalent Emissions		0	0.0

Detached house in Hohen-Neudorf, Germany
Photo: Ralf Lenk

33 "Climate Data" Worksheet

Climate plays a significant role in both the heat demand and the heating and cooling loads of a building. The data necessary for the calculation of these quantities are supplied in the **Climate Data** worksheet. The list of available locations includes monthly average temperature and surface solar irradiance values for a horizontal surface and the four cardinal vertical surface orientations. These data are used directly for the Monthly Method as well as in the **Cooling, Summer and Windows** worksheets. Ground temperatures are calculated either in the **Ground** worksheet if it is filled in, or via the **Climate Data** worksheet using a simplified building-independent algorithm. Data for the year/heating period are either tabulated for several locations or compiled from monthly data. Climate data for the heating and cooling loads were calculated by the PHI using dynamic building simulations.

The standard climate data was developed as a reference climate for Central European locations. Regional climate data should only be used for the reference locations of the particular climate data set or for a comparable location. For locations whose height differs greatly from the reference location, it is recommended to use the standard climate.

In addition to the German climate data set, PHPP 2007 includes data from Austria, Switzerland, the Benelux countries, and various cities throughout the rest of Europe and North America.

33.1 Standard Climate

The PHPP contains a standard climate data set derived from typical Central European climate conditions. This data can be used for locations throughout Germany for a location-independent energy model of a building design concept.

The standard climate can be selected via a drop-down menu in the **Climate Data** worksheet. Alternatively, "Regional Climate Data" can be selected.

Standard/Regional Climate: Select here.

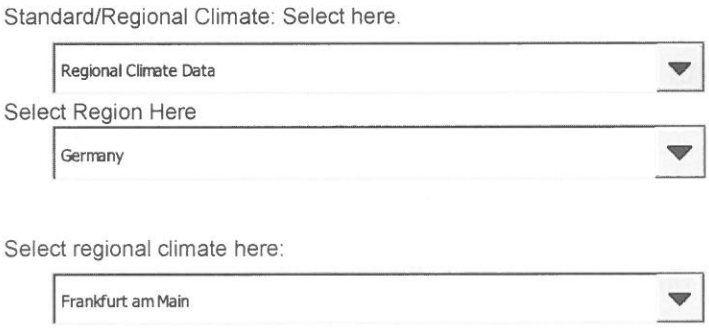
33.2 Regional Data

Besides the standard climate, regional climate data can also be used. These are based on monthly values – compatible annual values have been calculated by the PHI[5].

To choose a location in the **Climate Data** worksheet :

- In the first drop-down menu, select “Regional Data”
- In the second drop-down menu, select the desired geographic areas. The options are: Germany, Austria, Switzerland, Europe, the Benelux countries, USA, Canada and User Data.

In the third drop-down menu, select the desired geographic area from the scrollable list of available locations. The location is selected by clicking the location name.



The selected location will be shown in the upper right hand side of the worksheet and in the **Verification** worksheet. The following data are now available for calculation in other worksheets:

- Monthly data for the monthly method as well as the **Summer** and **Cooling** worksheets.
- Annual data for the annual method in the **Annual Heat Demand** worksheet.
- Associated climate data for the **Heating Load** and **Cooling Load** worksheets.

No further selections or modifications in this worksheet are possible.

If, however, “User Data” is selected in the second drop-down menu, then user defined climate data must be entered in the bottom section of the worksheet; otherwise an error message appears.

The selected climate data become visible in the green area.

[5] These annual data are based on a shorter heating period than the standard climate data set. This is why the heating degree hours and the calculated heat loss appear lower. However, since the solar and internal gains are reduced as well, the overall balance for the annual heat demand does not lead to a lower value than if a longer heating period had been used.

elevation of the building site
(for higher altitudes)

Month	1	2	3	4	5	6	7
Days	31	28	31	30	31	30	31
Frankfurt am Main	Latitude:	50.2	Longitude ° East	8.7	Altitude m	125	
Ambient Temp	0.7	1.8	5.2	9.2	13.7	17.1	18.9
North	11	17	30	44	57	61	62
East	15	30	47	73	91	89	96
South	33	60	71	82	86	77	87
West	16	30	50	73	89	87	96
Global	23	44	74	115	150	150	162
Dew Point	-1.6	-1.3	1.3	3.8	7.9	11.0	13.0
Sky Temp	-9.0	-8.6	-4.7	-1.2	4.6	8.8	11.5
Ground Temp	10.5	10.0	10.2	11.0	12.1	14.1	15.0

Weather station latitude, longitude and altitude are shown in addition to temperature and irradiance data. Trans-regional data include an average latitude only; the other fields remain empty. An optional field for building site elevation (in meters above sea level) is included to the right of the cell for weather station elevation. Enter a value in this cell to correct for the difference in temperature due to difference in elevation of the building site and the weather station. For small differentials this field may be left blank.

Cells for dew point and sky temperatures are provided in addition to outside temperature and irradiance data, however dew point temperature is not included in every data set. The omission invalidates the calculation in the **Cooling Units** worksheet.

33.3 User Data

The user input data fields in the yellow area of the **Climate Data** worksheet are accessed by selecting "User Data" in the drop-down menu. The following information is required for each user created climate data set:

For each climate data set, all of the following is required:

- Outside monthly temperatures
- Average monthly horizontal solar irradiation and average monthly vertical irradiation for north, east, west and south surface orientations (in kWh/m^2)
- Location latitude (in decimal format)

	Example	Latitude:	50.2
° C	Ambient Temp	0.9	2
kWh/(m²*month)	North	9.0	15.0
kWh/(m²*month)	East	14.0	21.0
kWh/(m²*month)	South	30.0	33.0
kWh/(m²*month)	West	14.0	19.0
kWh/(m²*month)	Global	23.0	34.0
° C	Dew Point	0.3	-0.9
° C	Sky Temp	-9.0	-8.6

Enter temperature and irradiation data according to the surface orientation following the order shown in the second column. Note that monthly global irradiance values are in kWh(/m^2 month).

Enter a label in the second column above "Ambient Temperature" for the data set name. There are no naming conventions, so the user is free to create an appropriate label that clearly identifies the data set. This label will appear in the third drop-down menu and, when clicked on, will select the corresponding data set. The field to the left of the label indicates which annual data set is used in the **Annual Heat Demand** worksheet. This field is usually left blank so that annual data is calculated from input monthly data. If the user enters "Standard" into this field, then the standard data set will be used. If another name is entered into this field the worksheet will not recognize it and the input will be ignored.

Enter the average monthly dew point and sky temperatures to take full advantage of the algorithms embedded in PHPP 2007. If left blank they are estimated from available data.

Enter the weather station's elevation to correct for the temperature difference due to the difference in elevation of the building site.

If you do not have your own climate date, then the following can be done:

The Meteonorm climate program (Version 6.0 and upward) available at www.meteotest.ch has a filter to export to the PHPP 2007 data set format. The user can generate monthly data for any global location and import it into the PHPP 2007 **Climate Data** worksheet.

- Open PHPP 2007 and find an empty section in the User Data area (yellow cells) of the **Climate Data** worksheet.
- Import data generated in Meteonorm (*.dat) into Excel (tab separated).
- Copy the Meteonorm data into the yellow cells of the selected User Data. Enter the data manually cell-by-cell in the first row. *Note: Do not change the denominations in the second column, otherwise the worksheet will not allocate data correctly!*
- Check the data for plausibility, regardless of the source. Algorithms developed to date cannot be used without consideration for all types of applications, e.g. generating hourly values from monthly data, interpolating between locations, or generating sky temperatures.
- Take into account special climatic conditions, particularly in mountainous regions. For instance, radiation corrections may be necessary in snowy (high albedo) or foggy regions. Cities are another case as "heat islands" develop frequently due to reduced evaporation, heat loads generated from human

activities and higher absorption of solar radiation. These factors can impact the usability of nighttime ventilation concepts for passive summer cooling. Adjustment to these micro-climatic conditions may be entered in the User Data section.

Note: The generation of heating and cooling load data is currently only accomplished using a dynamic simulation program. The *Passive House Institute* will provide heating and cooling data for the location if test reference years are available. If not available, the user may request this service from the *Passive House Institute*.

33.4 Climate Data for Heating and Cooling Load

In order to calculate the heating and cooling loads, corresponding data are necessary. These are displayed to the right of the monthly data. Most of the data sets included in PHPP 2007 contain such data. If load data are not present in the data set, no results are calculated in the **Heating Load** and/or **Cooling Load** worksheets.

If load data is available from another source, first copy the climate data to a new "User Data" data set then enter heating and cooling load data in the last three columns. Note that irradiation data must be in W/m^2.

If this is to be done, it is recommended to first copy the provided climate data to the User Data section and enter the load data there.

If you use your own climate data, particularly for locations outside Germany, the boundary conditions for the heating load calculations must be defined through dynamic simulation. The *Passivhaus Institute* offers this service.

33.5 PHPP in the Southern Hemisphere

Several calculations in PHPP 2007 assume that the latitude specified in the **Climate Data** worksheet is located in the northern hemisphere. For locations in the southern hemisphere the following workaround is suggested:

- Shift climate data by 6 months. Enter January climate data as July climate data and continue the same six-month shift for the remaining months.
- Mirror the location on the equator. Enter southern latitude as northern latitude.

34 "IHG" Worksheet: Calculation of Internal Heat Gains

The internal heat gains in residential buildings can be calculated using this worksheet based on the electricity demand in the **Electricity Non-Dom** and **Aux Electricity** worksheets. The result of the calculation can be transferred to the **Verification** worksheet and to the balance of heat demand by selecting „PHPP Calculation Residential" in the lower drop-down menu and manually entering the calculated value into the yellow cell to the right. These cells can, as an exception, not be linked, because otherwise a circular reference (Excel error message) will result.

If other types of use are applicable, a value that has been determined individually by the user can be entered (in W/m²). This value will automatically be used in the **Verification** worksheet, if in the drop-down menu in the **Verification** worksheet under building type "Residential", in the further menu a type of use and in the lower selection menu "PHPP Calculation Residential" has been selected.

For Passive House certification, the standard IHG values, when available, should be used. To accomplish this, the following options should be selected in the **Verification** worksheet: The applicable selection in the Building Type menu; the appropriate use (office, school, other) in the "Utilisation Pattern" menu; and "Standard" in the "Type of Values Used" menu.

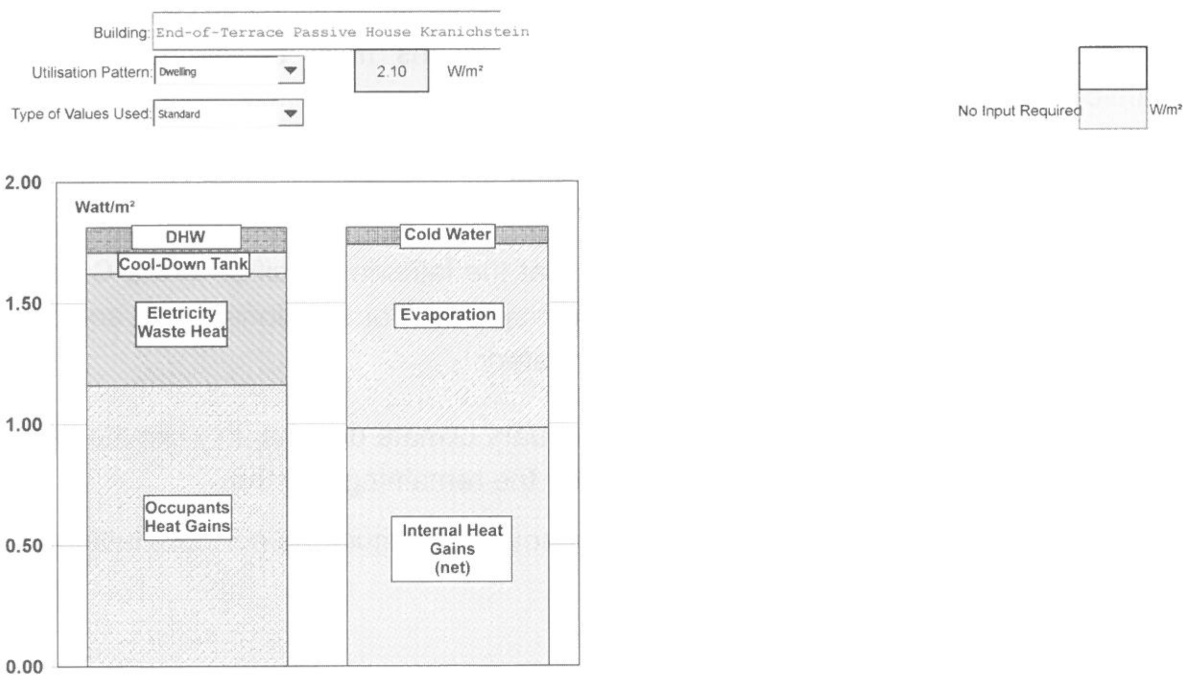


Figure 25: Balance of the internal heat gain supply: Results from measurements in the Passive House Darmstadt-Kranichstein, Germany (the measured electric energy demand is lower than in the sample file which has been determined with electric appliances available on the market)

The heat given off by electrical equipment plays an important role as an internal heat gain. Other factors, relevant for the balance of the heat gains, are the heat emission of occupants and the enthalpy loss caused by evaporation. If designed correctly, the building dependent gains and losses of hot and cold water pipes are only relevant to a lesser extent (see Figure 25).

Calculation Method

For each service the available free heating power (column 10) can be determined using the following formula:

$$Q_I = \frac{E_{Use} \cdot V_1 \cdot V_2}{t}$$

E_{Use}	column 6:	The useful energy demand calculated priorly
V_1	column 2:	Determines if the device is located inside or outside the thermal envelope, normally 0 or 1 (the value comes from the worksheet **Electricity** worksheet)
V_2	column 8:	The usability determines which fraction of the waste heat can be used in the building as an actual heat supply. For example hot water that runs down the sewer pipe from washing machines, dishwashers or cooking processes is not available any more, nor is all of the “free heat” usable for space heating. The usability is calculated in the **Annual Heat Demand** worksheet. The usability is based on [Feist 1994] and has been tested to match experiences in the Passive House Darmstadt Kranichstein, Germany.
t	column 9:	The duration of operation of the service; in the majority of cases 8760 hours (given value: 8.76 kh)

The specific free heating power q_I (second last row) is calculated using:

$$q_I = \frac{Q_I}{A_{TFA}}$$

The free heat results from the multiplication of the free heating power Q_I with the duration of the heating period (225 days or 5400 hours / year when using standard climate)

Passive House Planning

INTERNAL HEAT GAINS

Building: End-of-Terrace Passive House Kranichstein

Utilisation Pattern: Dwelling 2.10 W/m²

Type of Values Used: Standard

No Input Required W/m²

Calculation Internal Heat Household

Persons 4.5 P; Living Area 156 m²

Annual Heat Dem 12 kWh/(m²a); Heating Period 205 d/a

Column Nr.	1	2	3		4	5		6		7	8		9		10
Application	Existing (1/0), or number of people	In the Thermal Envelope (1/0)	Norm Consumption		Utilization Factor	Frequency		Useful Energy (kWh/a)		Included in Electricity Balance?	Availability		Used During Time Period (kh/a)		Internal Heat Source (W)
Dishwashing	1	1	1.1	kWh/Use	1.00	65	/(P*a)	319	*		0.30	/	8.76	=	11
Clothes Washing	1	1	1.0	kWh/Use	1.00	57	/(P*a)	241	*		0.30	/	8.76	=	8
Clothes Drying with:	1	0	0.0	kWh/Use	0.88	57	/(P*a)	0	*		1.00	/	8.76	=	0
Clothesline		0	0.0					0			0.80				
Energy Consumed by Evaporation	1	0	0.0	kWh/Use	0.60	57	/(P*a)	0	* (1-	1) *	1.00	/	8.76	=	0
Refrigerating	1	1	0.3	kWh/d	1.00	365	d/a	102	*		1.00	/	8.76	=	12
Freezing	1	0	0.6	kWh/d	0.90	365	d/a	181	*		1.00	/	8.76	=	0
or Combination	0	1	0.7	kWh/d	1.00	365	d/a	0	*		1.00	/	8.76	=	0
Cooking	1	1	0.3	kWh/Use	1.00	500	/(P*a)	557	*		0.50	/	8.76	=	32
Lighting	1	1	20.8	W	1.00	2.9	kh/(P*a)	269	*		1.00	/	8.76	=	31
Consumer Electronics	1	1	80.0	W	1.00	0.55	kh/(P*a)	196	*		1.00	/	8.76	=	22
Household Appliances/Other	1	1	50.0	kWh	1.00	1.0	/(P*a)	223	*		1.00	/	8.76	=	25
Auxiliary Appliances (cf. Aux Electricity Sheet)														=	5
Other Applications (cf. Electricity Sheet)	0	0.0						0	*		0	/	8.76	=	0
Persons	4	1	80.0	W/P	1.00	8.76	kh/a	3124	*		0.55	/	8.76	=	196
Cold Water	4	1	-5.0	W/P	1.00	8.76	kh/a							=	-22
Evaporation	4	1	-25.0	W/P	1.00	8.76	kh/a	-976	*		1.00	/	8.76	=	-111
Total													W		**209**
Specific Demand													W/m²		**1.34**
Heat Available From Internal Sources										205 d/a			kWh/(m²a)		**6.6**

35 "IHG Non-Dom" Worksheet: Calculation of Internal Heat Gains in Non-Residential Buildings

The internal heat gains in non-residential buildings can be calculated using this worksheet. If the building utilization pattern differs from the standard use of a non-residential building (office, school), then the default values should be examined more closely. To activate this worksheet, the building type "Non-residential" must be selected in the **Verification** worksheet. The internal heat gains are calculated from the electricity demand in the **Electricity Non-Dom** and **Aux Electricity** worksheets. Therefore, these two worksheets must be fully filled out before the internal heat gains can be calculated. Lastly, in the "Type of Values Used" drop-down menu, "PHPP Calculation Non-Residential" must be selected. The calculated result must be entered in the yellow field at the top of the **IHG Non-Dom** worksheet in order to be included in the heat demand calculation and to appear in the **Verification** worksheet. Moreover the drop-down menu "Type of Values Used" must be set to „PHPP Calculation Non-Residential“

For Passive House certification, the standard IHG values, when available, should be used. To accomplish this, the following options should be selected in the **Verification** worksheet: "Non-residential" in the Building Type menu; the appropriate use (office, school, other) in the "Use" menu; and "Standard" in the "Type of Values Used" menu. The last two drop-down menus can also be found at the top of the **IHG Non-Dom** worksheet.

At the top of the worksheet, the internal gains of the occupants are calculated. Selecting the utilization profile determines the number of annual utilization hours and the relative occupancy of the building. The utilization profiles are found in the **Use Non-Dom** worksheet; additional profiles can also be defined. In addition, the activity of the occupants must be chosen. The number of occupants can either be directly entered or determined using the utilization zone's floor area (as long the average occupancy has been entered in the utilization profile).

The internal gains from electrical devices used in the building are summarized in the second section.

Below this, the influence of cold water use for toilet flushing is calculated. The chosen user profile determines the number of utilization days and daily utilization hours. Additionally, the number of toilets with toilet tanks must be entered. For schools, the number of toilets can be estimated from the number of occupants found at the top of the worksheet.

Passive House Planning

INTERNAL HEAT GAINS Non

Building: End-of-Terrace Passive House Kranichstein

Utilisation Pattern: Office

Type of Values Used: Standard

3.50 W/m²

No Input Required

Calculation Internal Heat — Column Nr.

Persons: 4 P — TF Area: 156 m² — Heating Period: 225 d/a — Room Temperature: 20 °C — Internal Heat Gains Aux. Electricity: 5.0 W

Persons	Select	Utilisation Pattern	Select	Activity of Persons	Planning with the number of persons or via floor area of utilisation zone (planning via area only if the occupancy is available for this utilisation pattern). Pers./Area (1 / 0)		Number of Occupants		Floor Area of Utilisation Zone (m²)	Average Occupancy (Persons / m²)	Heat Emitted per Person (W)	Utilisation Hours per Year [h/a]	Relative Presence	Used in Time Span (h/a)	Average Heat Emitted by Persons (W)
Persons A	22	Group Office	2	> 10 yr., sitting	1	planning with # of persons	4	or		no standard value	80	2750	0.70	8760	70
Persons B	0		2	> 10 yr., sitting	1	enter # of persons or floor area		or		no standard value	80	0	1.00	8760	0
Persons C	0		2	> 10 yr., sitting	1	enter # of persons or floor area		or		no standard value	80	0	1.00	8760	0
Persons D	0		2	> 10 yr., sitting	1	enter # of persons or floor area		or		no standard value	80	0	1.00	8760	0
Persons E	0		2	> 10 yr., sitting	1	enter # of persons or floor area		or		no standard value	80	0	1.00	8760	0
Persons F	0		2	> 10 yr., sitting	1	enter # of persons or floor area		or		no standard value	80	0	1.00	8760	0
Persons G	0		2	> 10 yr., sitting	1	enter # of persons or floor area		or		no standard value	80	0	1.00	8760	0
Evaporation (person specific)							4				-15	2750	0.70	8760	-13

Lighting / Equipment / Aux. Electricity	Useful Energy [kWh/a]	Availability	Used in Time Period (kh/a)	Average Heat Release
Lighting	1384	1.00	8.76	158
Office Applications (Within Therm. Envelope)	2597	1.00	8.76	296
Cooking (Within Therm. Envelope)	0	0.50	8.76	0
Dishwashing (Within Therm. Envelope)	0	0.30	8.76	0
Cooling (Within Therm. Envelope)	140	1.00	8.76	16
Other (Within Therm. Envelope)	50	1.00	8.76	6
Auxiliary Appliances (See Aux Electricity Worksheet)				5

Heat Loss Due to Cold Water (calculation from column AJ)	on/off (1 / 0)		Predominant Utilisation Pattern of Building (Data transfered from Electricity Non-Dom worksheet; input kitchen)	Number of WCs (user data)	Number of WCs. Use standard value for schools (X)	Number of WCs (calculation value)	ΔT: Cold Water Temp. - Room Temp. [K]	Occupied Days per Year [d/a]	Loss Daytime [W]	Loss Nighttime [W]	Availability	Used in Period (d/a)	Average Power Cold Water
Cold Water Due to Flushing WC	1	0		2		2	-8	0	0	-8	1.00	365	0

Total		W	538
Specific Demand		W/m²	3.5
Heat Available From Internal Sources	225 d/a	kWh/(m²a)	19

36 "Use Non-Dom" Worksheet: Non-residential Buildings User Profiles for the Calculation in Electricity Non-Dom and IHG Non-Dom

In the **Use Non-Dom** worksheet user profiles for non-residential buildings are given. These are necessary exclusively for the worksheets **Electricity Non-Dom** and **IHG Non-Dom**.

In the upper part of the worksheet individual user profiles can be defined. Further down predefined use-profiles according to [DIN V 18599-10] are given. For the definition of individual use-profiles, the latitude has to be entered at first (this influences the number of hours in use at night). With each entry in a row a use-profile is being defined. The profile describes the typical use in a part of the building. For an individual profile, at least the yellow cells up to column 20 have to be filled in.

- **Illumination Level**: Required illumination level in the part of the building in question [lux]
- **Relative Absenteeism**: "This gives the fraction of the time in use, in which no person is in the calculated part of the building (0: permanent occupancy, 1: no occupancy). The relative absenteeism takes a temporary partial use during a use day into account (for example: meetings, breaks, etc.)." (Excerpt from DIN V 18599-10).
- **Part Use Factor of Building Operating Period for Lighting**: "This factor determines to what extent the use time given for the corresponding use profile can be reduced when calculating the energy demand for lighting. The partial use factor takes a temporary partial use during the balance period into account (for example: holidays, vacations, illness, etc.)." (Excerpt from DIN V 18599-10).

Production and office building in Zwingenberg, Germany
Photo: Passive House Institute

Passive House Planning

U T I L I S A T I O N Non-domestic Use

Building: End-of-Terrace Passive House Kranichstein

Latitude [°]: 50

	2	3	4	5	6	7	8	9	10	11	15	16	17	18	20	27
	Utilisation Pattern		Periods of Utilisation and Operation	Begin Utilisation [h]	End Utilisation [h]	Daily Utilisation Hours [h/d]	Annual Utilisation Days [d/a]	Annual Utilisation Hours [h/a]	Annual Utilisation Hours During Daytime [h/a]	Annual Utilisation Hours During Nighttime [h/a]	Illumination Level [lux]	Height of Utilisation Level (0.8 or 0.0m)	Height of Utilisation Level (0.8 or 0.0m)	Relative Absenteeism	Part Use Factor of Building Operating Period for Lighting	Average Occupancy [m²/Pers.]
1						0		0	0	0			0.80			
2						0		0	0	0			0.80			
3						0		0	0	0			0.80			
4						0		0	0	0			0.80			
5						0		0	0	0			0.80			
6						0		0	0	0			0.80			
7						0		0	0	0			0.80			
8						0		0	0	0			0.80			
9						0		0	0	0			0.80			
10						0		0	0	0			0.80			
11						0		0	0	0			0.80			
12						0		0	0	0			0.80			
13						0		0	0	0			0.80			
14						0		0	0	0			0.80			
15						0		0	0	0			0.80			
16						0		0	0	0			0.80			
17						0		0	0	0			0.80			
18						0		0	0	0			0.80			
19						0		0	0	0			0.80			
20						0		0	0	0			0.80			
21	Single Office			7	18	11	250	2750	2543	207	500	0.80	0.80	0.30	0.70	10.00
22	Group Office			7	18	11	250	2750	2543	207	500	0.80	0.80	0.30	0.70	
23	Open-Plan Office			7	18	11	250	2750	2543	207	500	0.80	0.80	0.00	1.00	15.00
24	Meeting			7	18	11	250	2750	2543	207	500	0.80	0.80	0.50	1.00	2.00
25	Counter Area			7	18	11	250	2750	2543	207	200	0.80	0.80	0.00	1.00	
26	Retail			8	20	12	300	3600	2999	601	300	0.80	0.80	0.00	1.00	7.00
27	Classroom			8	15	7	200	1400	1398	2	300	0.80	0.80	0.25	0.90	2.00
28	University Auditorium			8	18	10	150	1500	1409	91	500	0.80	0.80	0.25	0.70	0.75
29	Bedroom			0	24	24	365	8760	4407	4353	300	0.80	0.80	0.00	0.50	
30	Hotel Room			21	8	11	365	4015	755	3260	200	0.80	0.80	0.25	0.30	
31	Canteen			8	15	7	250	1750	1748	2	200	0.80	0.80	0.00	1.00	
32	Restaurant			10	0	14	300	4200	2404	1796	200	0.80	0.80	0.00	1.00	1.50
33	Kitchen Non-Residential			10	23	13	300	3900	2404	1496	500	0.80	0.80	0.00	1.00	
34	Kitchen, Storage, Preparation			7	23	16	300	3900	2404	1496	300	0.80	0.80	0.50	1.00	
35	WC, Sanitary			7	18	11	250	2750	2543	207	200	0.80	0.80	0.90	1.00	
36	Other Habitable Rooms			7	18	11	250	2750	2543	207	300	0.80	0.80	0.50	1.00	
37	Secondary Areas			7	18	11	250	2750	2543	207	100	0.80	0.80	0.90	1.00	
38	Circulation Area			7	18	11	250	2750	2543	207	100	0.00	0.00	0.80	1.00	
39	Storage, Services			7	18	11	250	2750	2543	207	100	0.80	0.80	0.98	1.00	
40	Server Room			0	24	24	365	8760	4407	4353	500	0.80	0.80	0.50	0.50	
41	Workshop			7	16	9	250	2250	2192	58	500	0.80	0.80	0.00	1.00	
42	Theater Auditorium			19	23	4	250	1001	55	946	200	0.80	0.80	0.00	1.00	
43	Theater Foyer			19	23	4	250	1001	55	946	300	0.80	0.80	0.50	1.00	
44	Theater Stage			13	23	10	250	2500	1253	1247	1000	0.80	0.80	0.00	0.60	
45	Fair, Congress			13	18	5	150	1350	1260	90	300	0.80	0.80	0.50	1.00	
46	Exhibition			10	18	8	250	2001	1850	151	200	0.80	0.80	0.00	1.00	
47	Library Reading Room			8	20	12	300	3600	2999	601	500	0.80	0.80	0.00	1.00	
48	Open Access Library			8	20	12	300	3600	2999	601	200	0.80	0.80	0.00	1.00	
49	Library Repository			8	20	12	300	3600	2999	601	100	0.80	0.80	0.90	1.00	
50	Gymnasium			8	23	15	300	4500	3002	1498	300	0.80	0.80	0.30	1.00	
51	Parking Garage			7	18	11	250	2750	2543	207	75	0.00	0.00	0.95	1.00	
52	Public Parking Garage			9	0	15	365	5475	3290	2185	75	0.00	0.00	0.80	1.00	
53																
54																

37 Excel File: Final Protocol Worksheets Ventilation

For the correct operation of the ventilation system, the air volume flow rates for each room have to be designed and adjusted. It is important that each room is provided with supply and extract air by the ventilation system, either with a supply air valve, an extract air valve or as a flow-through zone.

37.1 Final Protocol Worksheet: Design

- Input of project data:
  Enter the building project and the ventilation system consultant
- Standard use or special requirements:
  If the ventilation is not dimensioned for standard-use operation, special requirements can be given here
- Criteria for dimensioning the airflow volumes:
  Number of occupants (30 m^3 fresh air per person and hour)
  Number of extract air rooms for the extract air demand
  The dimensioning of the nominal air flow volume for standard operating mode is based on the fresh air demand.
- Distribution of the air volume flow rate:
  Data for all rooms inside the thermal envelope are to be entered here. The total sum of supply air and the total sum of extract air have to be equal. The type of flow-off vent is to be given for each room.
- Adjusted airflow volumes, control range:
  The base ventilation should be 30 % lower and the peak ventilation 30 % higher than the standard operation (nominal air volume flow rate). The air flow rate should not fall below 0.30 / h (minimum air flow rate for hygienic reasons).
- Efficiency requirements:
  The product type of the ventilation unit, the efficiency of heat recovery and the electricity demand according to the PHI-method.
- Requirements for noise protection:
  In living space 25 dB(A) max.
  In the room in which the unit is located 35 dB(A) max.
- Hygienic requirements:
  filter grade: fresh air intake F7 min., exhaust air output G3 min.
- Recommendation:
  extract air coarse filters at least in laundry rooms, grease condensation filters in the kitchen

37.2 Final Protocol Worksheet: Initial Start-Up

- Each valve (supply and extract air) and the air flow rates for fresh air and exhaust air are to be adjusted with up to 3 measurement cycles. The design air flow rates (Final Protocol Worksheet: Design) are to be adjusted as accurately as possible (the maximum difference between supply air and extract air is 10 %). The type of valve and it's adjustment setting (gap width, number of hole rows etc.) are to be documented.
- The disbalance of the air flow volumes between fresh air and exhaust air may not exceed 10 %
- Checking: For a limitation of the pressure losses the maximum air flow velocity in the flow-off vent is 1m/s (pressure drop 1 Pa max.).
- Filter check (filter grade, direction of installation, filter fit)
- Check of the demands on noise protection

Apartment-building in Tübingen, Germany
Photo: F. Förster

Office building lu·teco in Ludwigshafen; Germany
Photo: Passive House Institute

38 Symbols and Definitions

Symbol	Unit	Description
$1/\alpha_i$, $1/\alpha_e$	m^2K/W	Thermal Resistance
A	m^2	Area
A_{TFA}	m^2	Treated floor area
A_{Window}	m^2	Window area (rough opening dimensions)
A_{Frame}	m^2	Frame area
A_G	m^2	Glazing area
c_P	$Wh/(m^3K)$	Volumetric heat capacity of air: 0.33 Wh/(m3K)
d_e	m	Exterior dimensions
d_{Hori}	m	Shading object horizontal distance to the shading edge
d_i	m	Interior dimensions
d_{over}	m	Distance of overhang (vertically) to the glazing edge
$\Delta\vartheta$	K	Temperature difference between interior and exterior
E		Wind protection coefficient
e_g		Efficiency of the heat generation
ϕ	Degree	Angular deviation from North (Windows)
f_{el}		Fraction of services provided by electricity
f_{solar}		Fraction of hot water demand provided by solar thermal systems
f_T		Reduction factor for weighting of temperature difference
f_{use}		Utilisation factor for correction of standard energy consumption value
Φ_{HR}	%	Heat Recovery Efficiency
g	%	Degree of total energy transmission
G	$kWh/(m^2a)$	Global irradiation (Solar irradiation on a horizontal surface)
G_t	kKh/a	Heating Degree Hours (thousands)
H		Frequency of use per annum and per reference parameter
h_G	m	Window glazing height

Symbol	Unit	Description
h_{Hori}	m	Shading object height from the lower edge of the glazing
$l_1, ..., l_n$	m	Layer dimension of the layer 1, ..., n for building elements
η_{HR}	%	Efficiency of heat recovery of the plate heat exchanger
η_{SHX}	%	Efficiency of heat recovery of the subsoil heat exchanger
η_{Solar}	%	Solar use rate
$\vartheta_{Supply,max}$	°C	Maximum supply air temperature: 52 °C
$\vartheta_{Supply,min}$	°C	Minimum supply air temperature without supplementary heating
ℓ	m	Length (e.g. of a linear thermal bridge)
λ	W/mK	Thermal conductivity
n_{50}	h^{-1}	Air change rate @ 50 Pa pressure
$n_{V,Res}$	h^{-1}	Infiltration air change rate
n_V	h^{-1}	Energetically effective air change rate
$n_{V,System}$	h^{-1}	Average air change rate of the ventilation system
$\nu_{Additional}$		Relative additional energy demand due to a domestic hot water connection (washing machine and dishwasher)
o_{over}	m	Length of overhang (horizontally) measured from the exterior glass surface
p	kWh/kWh	Primary energy factor
Θ	Degree	Angle of inclination from vertical (Windows)
Q_{1Dim}	W	One-dimensional heat flow
Q_{2Dim}	W	Two dimensional heat flow
Q_{Final}	kWh/a	Final energy demand
Q_{Use}	kWh/a	Useful heat demand (space heating + DHW)
Q_P	kWh/a	Primary energy demand
r	%	Reduction factor for solar irradiation
r_{Dirt}		Reduction factor due to dirt on windows
r_{Frame}		Reduction factor due to the window frame
r_H		Reduction factor due to shading from a row of houses
$r_{incidence\text{-}angle}$		Reduction factor due to inclined radiation

Symbol	Unit	Description
r_R		Reduction factor due to shading from window reveals
r_O		Reduction factor due to shading from overhangs
r_S		Reduction factor due to shading
s		Indicates if the considered appliance / service is exists
U	W/(m²K)	Heat transfer coefficient (U-value)
u_{CO2}	kg/(m²a)	Specific annual CO_2 emissions equivalent
U_{CO2}	kg/a	Annual CO_2 emissions equivalent
U_{Frame}	W/(m²K)	Heat transfer coefficient of the window frame
$U_{Glazing}$	W/(m²K)	Heat transfer coefficient of the window glazing
V_1	-	Appliance within (=1) or outside (=0) of the thermal building envelope
V_2	-	Availability of waste heat from appliances as interior heat gain
V_{Norm}	kWh/Serv.	Standard consumption of the considered appliance
V_V	m³	Air exchange reference volume for the ventilation system
x_{CO2}	g/kWh	CO_2 – emissions factor equivalent per kWh of final energy
Ψ_e	W/(mK)	Linear thermal transmittance, exterior reference dimension
$\Psi_{Installation}$	W/(mK)	Linear thermal transmittance, window installation
Ψ_{Spacer}	W/(mK)	Linear thermal transmittance, glazing edge
Ψ_i	W/(mK)	Linear thermal transmittance, interior reference dimensions
z	-	Reduction factor for temporary sun protection devices

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